Paint and Varnish
Production Manual

Paint and Varnish Production Manual

Edited by

VERNE C. BIDLACK
President
Pennsylvania Color and Chemical Company

EDGAR W. FASIG
General Superintendent
The Lowe Brothers Company

NEW YORK · JOHN WILEY & SONS, INC.
LONDON · CHAPMAN & HALL, LIMITED

CATALOGUED BY Suri

Copyright, 1951
by
John Wiley & Sons, Inc.

All Rights Reserved

This book or any part thereof must not be reproduced in any form without the written permission of the publisher.

ALLAMA IQBAL LIBRARY
10672

ST 01
RG1

JAMMU & KASHMIR UNIVERSITY
LIBRARY
No 10672.
Date 23.4.55.
SRINAGAR

CHECKED

667.602
B 474 P

PRINTED IN THE UNITED STATES OF AMERICA

Prepared for the

FEDERATION

of

PAINT and VARNISH PRODUCTION CLUBS

PREFACE

For many years, the need for assembling in one volume the basic knowledge of production facilities and methods employed by the paint industry has been recognized. In 1944, the Materials and Manufacturing Committee prepared a prospectus of information essential to the manufacture of paint and allied products for the approval of the Federation of Paint and Varnish Production Clubs which has sponsored the publication of this book.

The Manual has been designed for the education of production personnel in the manufacture of surface coatings and for those interested in the problems of management. All who are responsible for transforming company policies into tangible results in this and similar industries will obtain many valuable suggestions from its contents.

Although compact in form, products and plant requirements for the manufacture of paints, varnishes, and lacquers according to established procedure are sufficiently described for supervisory purposes. The proper use of equipment and the processing of materials are considered with regard to engineering fundamentals.

Personnel and associated problems are discussed with the thought of strengthening employer-employee relations through informed supervision.

Factors of cost govern the successful operation of all industrial plants, and an approved method of determining factory costs is explained and demonstrated.

The discussion of laboratory procedure has been limited intentionally to those functions of interest to production management. Specific information on the subject matter can be obtained in the reference literature.

Adequate protection against damage by fire and precautions for the safety and health of employees are recommended to complete the scope of the *Paint and Varnish Production Manual* which will serve as a guide and source of instruction for all who share the responsibilities of production.

The paint, varnish, and lacquer industry has accepted many changes in common with all fields of manufacturing wherein new materials, production methods, and personnel policies have had a marked effect on the development and application of engineering principles. A simplified correlation of modern practices is presented herewith.

VERNE C. BIDLACK
EDGAR W. FASIG

September, 1951

CONTENTS

CHAPTER 1

PHYSICAL FACILITIES

In general, the layout of a paint manufacturing plant follows closely the pattern established for the production of all package and bulk merchandise and varies in detail only as specific requirements for the manufacture of paint and related products dictate.

The variation in size of manufacturing companies and of their production units does not alter the essential requirements for successful operation. A large plant is only a multiple of the facilities and personnel of a smaller plant. In either, a certain minimum of personnel and mechanical operations is required. The same functions exist in all plants and must be carried out in every organization. Increasing the volume of business is simply a matter of extending and assigning the primary functions to departments for systematic control.

Location

The best location for a manufacturing plant is a site where the combined cost of production and distribution of the product is relatively low. Other conditions being equal, the company will be handicapped in meeting competition to the extent to which its location contributes to increased expense.

A paint production plant serving a small area must necessarily be located within that area. Large concerns, which have wide distribution, will usually be centrally located. Many of these companies simplify their problems of delivery by locating manufacturing units or warehouses at key points throughout the whole area to be served.

Among the factors influencing the geographic location for a plant are: market, raw materials, labor, transportation, power, and fuel. Secondary factors include: legislation, climate, water supply, and waste disposal.

A choice among local sites will involve a comparison of land values, character of property (contour of ground, soil conditions, or shape of plot), room for expansion, housing accommodations, public utilities and improvements, rail and truck facilities, labor conditions, building laws, local ordinances, and taxes.

The location of the plant can determine the eventual success or failure of the enterprise. It should be emphasized that a centrally situated plant is most important to small concerns and to those in the medium-small bracket. A plant in either of these categories, having the distinct advantage of serving customers with a minimum of distribution costs, can compete with larger manufacturers whose costs are considerably greater.

All forms of transportation costs must be considered, and facilities should be adequate to avoid excessive overhead costs in the flow of raw and finished materials to and from the plant.

The initial outlay for land and buildings is always important to a new enterprise. The size and general design of the manufacturing units may be limited by the costs involved. The choice between a large manufacturing district, a small community, or a suburban area for the location of a plant is a matter that requires careful study before making a final decision.

Large cities have many advantages, such as labor market, shipping facilities, public utilities, and social activities for employees. On the other hand, property is usualy more expensive, taxes may be greater, wages will probably be higher, and transportation of employees may be less convenient.

The small community, although offering a limited labor market, often provides better workmen at lower rates and civic interests which may be more conducive to stability and less turnover of personnel. These favorable labor conditions, however, may be accompanied by problems involving utilities and services which do not exist in large manufacturing centers.

Informed management will generally agree that a suburban location for a new plant is the most desirable of the three alternatives. The typical suburb usually has the advantages of both the big city and the small town but has few of their inherent disadvantages.

For the manufacture of paint and varnish, the encumbrances of local statutes and state regulatory laws should be investigated thoroughly to avoid restrictions common to the industry. Certain operations are considered hazardous or undesirable in residential districts and are subject to zoning restrictions which must be respected.

Plant Design

The character of the plant may depend on a previously acquired location, or approved plans for manufacturing may demand the purchase of property to meet the projected requirements.

Obviously, the ideal arrangement will permit designing the plant with

complete consideration for efficient production and distribution of a specified volume. The building may then be constructed to conform to the layout, and a site of adequate size may be obtained for the purpose.

If the location is acquired first, then careful study will be necessary to select the most effective layout for fixed conditions.

A comparatively small site will almost inevitably demand a multi-floor building, whereas a single-floor structure may be preferable if sufficient ground area is available.

Some of the problems associated with plant layout are so controversial that no attempt can be made to recommend a definite procedure for overcoming each difficulty.

Obviously, it is important to consider future expansion when the initial plans are proposed. Even normal growth of a successful business can demand additional production capacity in a short time. In order to avoid costly remodeling of a plant in operation, a safe margin for expansion should be provided.

Several plans for the production of a general line of protective coatings are illustrated in Chapter 2. They are sufficiently flexible in design to permit modification as it may be desired. Obviously, individual companies specializing in the manufacture of specific products may employ entirely different methods. Local conditions and personal preferences often dictate extraordinary changes in usual operating procedures.

In general, the plant should be designed to facilitate and coordinate the various manufacturing processes, to minimize noise and vibration, to provide good illumination and ventilation, to ensure the utmost in safety and pleasant working conditions for employees, to permit low maintenance costs, to possess a certain degree of flexibility, to present a neat and attractive appearance, and to secure maximum production at minimum costs for the capital invested.

The single-story building has several fundamental advantages, such as unlimited illumination from natural sources, dimensional flexibility for expansion, and low engineering costs.

Manufacturing on one level also has many advantages. Heavy equipment can rest on solid foundations. Elevators, ventilators, and other non-productive space are avoided, and the cost of transferring materials from one department to another is kept at a minimum. On the other hand, construction costs per square foot of single-floor buildings are usually greater than for multi-floor buildings.

In addition to providing a maximum of floor area within limited ground space, the multi-floor building permits the gravity flow of materials from the primary mixing operations to the warehouse and loading

platforms. Nevertheless, provision must be made for the transfer of raw materials to top floors; here definite limitations on floor loads are encountered. Obviously, buildings of more than one floor must be narrow to permit general illumination from natural sources.

Space will not permit a discussion of the relative merits of wood, brick, and reinforced concrete as construction materials. The material selected will depend on building restrictions, local conditions, and permissible investment. Multi-story buildings should be erected in a manner that allows placement of equipment between floors without weakening the floors involved or the main structure. Modern construction provides for alterations which eventually may be necessary, for example, the removal of part or all of a floor in any bay without damage to the building as a whole.

Plant layout has been defined as "the determination and development of the physical relations of plant, equipment, and operations leading to an advanced degree of economy and effectiveness in manufacturing." Good plant layout involves eliminating points of congestion in the flow of work. Careful study is required to abolish unnecessary operations and to combine others so that maximum efficiency may be obtained.

Materials-Handling Requirements

In paint and varnish making, as in almost any industrial process, a great part of the necessary labor is employed in handling materials. The functions of paint and varnish production that involve materials handling are processing, internal transportation, and storage. From the arrival of the raw materials to the shipping of the finished products, materials must be routed efficiently into, through, and out of each department. To reduce costs, all possible mechanical means should be used and the material should be kept moving in one direction.

Efficient materials-handling equipment and methods should attain the following objectives: (*a*) lower unit cost of moving and handling materials, (*b*) reduction and more rapid turnover of inventories, (*c*) greater production per employee, (*d*) better production control, (*e*) release of valuable factory floor space, (*f*) better control of quality, and (*g*) improved morale.

Rules Applying to Handling Materials

Know the various types of handling devices available.
Analyze routing of materials carefully.
Visualize actual needs for each job.
Select equipment when building is planned.
Buy for operating savings, not first cost.

Discuss problems with designers and manufacturers.
Rearrange equipment systematically.
Teach operators the possibilities of mechanized units.
Maintain handling equipment as carefully as production machinery.

There are various types and kinds of materials-handling equipment, many of which have been standardized. Some are for bulk items, some for package items, some for continuous delivery, others for non-continuous delivery. They include immobile, portable, and self-propelled units.

Equipment. The following general classification is considerably abridged but includes much of the materials-handling equipment used in paint and varnish production:

1. Trackless transportation
   - Platform trucks.
   - Hand trucks.
   - Lift trucks.
   - Electric or gasoline trucks and tractors.
   - Truck cranes.
   - Trailer cars.
2. Package-handling equipment
   - Roller skate, flat-roll, gravity-roll, and live-roll conveyors.
   - Belt conveyors.
   - Slat and platform conveyors.
   - Carousel, monorail chain conveyors and telphers.
   - Push-bar elevators.
   - Chutes.
   - Skids and pallets.
3. Hoisting machinery
   - Cranes of various types.
   - Hoists.
   - Cable and tramways.
4. Installations for loose materials
   - Skip hoists.
   - Screw conveyors.
   - Continuous bucket conveyors.
   - Gravity conveyors.
   - Belt conveyors.
   - Pneumatic conveyors.
5. Elevators
6. Industrial rail transportation
   - Locomotives.
   - Cable cars.
   - Hand-propelled cars.

Installation. When portable units, such as electric trucks and tractors, are employed it is essential to have sufficient charging capacity for batteries and proper facilities for their maintenance and repair. Installa-

tions of approved electric conduits and conductors are necessary for electric hoists. For fixed equipment such as cranes, elevators, and various types of conveyors, strength in design and general adaptability for rigid anchoring to foundations, floors, and ceilings must be considered to reduce vibration.

Maintenance. Handling equipment is so diversified that it is often neglected in general plant-maintenance inspection. It is essential to allot to certain operators the responsibility of equipment inspection. One of the most frequent abuses is improper lubrication and failure to repair or replace small parts. Repairs and replacements should be made immediately upon discovery. If parts break frequently, an investigation should be made to determine if the unit is in line, properly lubricated, and not subject to overloading or tampering.

Materials-handling equipment, when properly designed and applied, has the lowest maintenance costs of any of the mechanical devices around the plant.

Trucks and Mobile Units. Manually operated or hand trucks of many different sizes and shapes form an important part of materials-handling equipment in paint and varnish plants for moving loads within a radius of 200 ft. For distances of 50 ft or less, no other method is sufficiently flexible to move a variety of materials in any desired direction. Hand trucks also serve as movable platforms for pallet loads. They are customarily operated at 2 mph with loads varying from 250 to 750 lb.

Industrial Trucks. In plants where goods are transported more than 50 ft within the premises or outdoors, power-driven trucks are likely to be the most efficient and economical method. These trucks, which are driven by electric motors and storage batteries or gasoline engines, are capable of carrying direct loads of about 2 tons. They can traverse narrow aisles, turn sharp corners, climb ramps, run into crowded places, and go on and off elevators and into box cars. Power-driven trucks require more working space than hand trucks; however, their speed in handling materials and their ability to stack to considerable heights and put most of the cubage of a given space to work more than offset the increase in aisle area that they require. Also, operators of industrial power-driven trucks are able to work longer and with less physical strain than operators of hand trucks.

Industrial trucks may be classified as load-carrying, low-lift (platform), and fork trucks. They vary considerably with the type chosen and its capacity. Fork trucks are used extensively in paint and varnish plants for picking up and tiering large drums as well as pallets of smaller cases and cans. They are more versatile than platform trucks since they

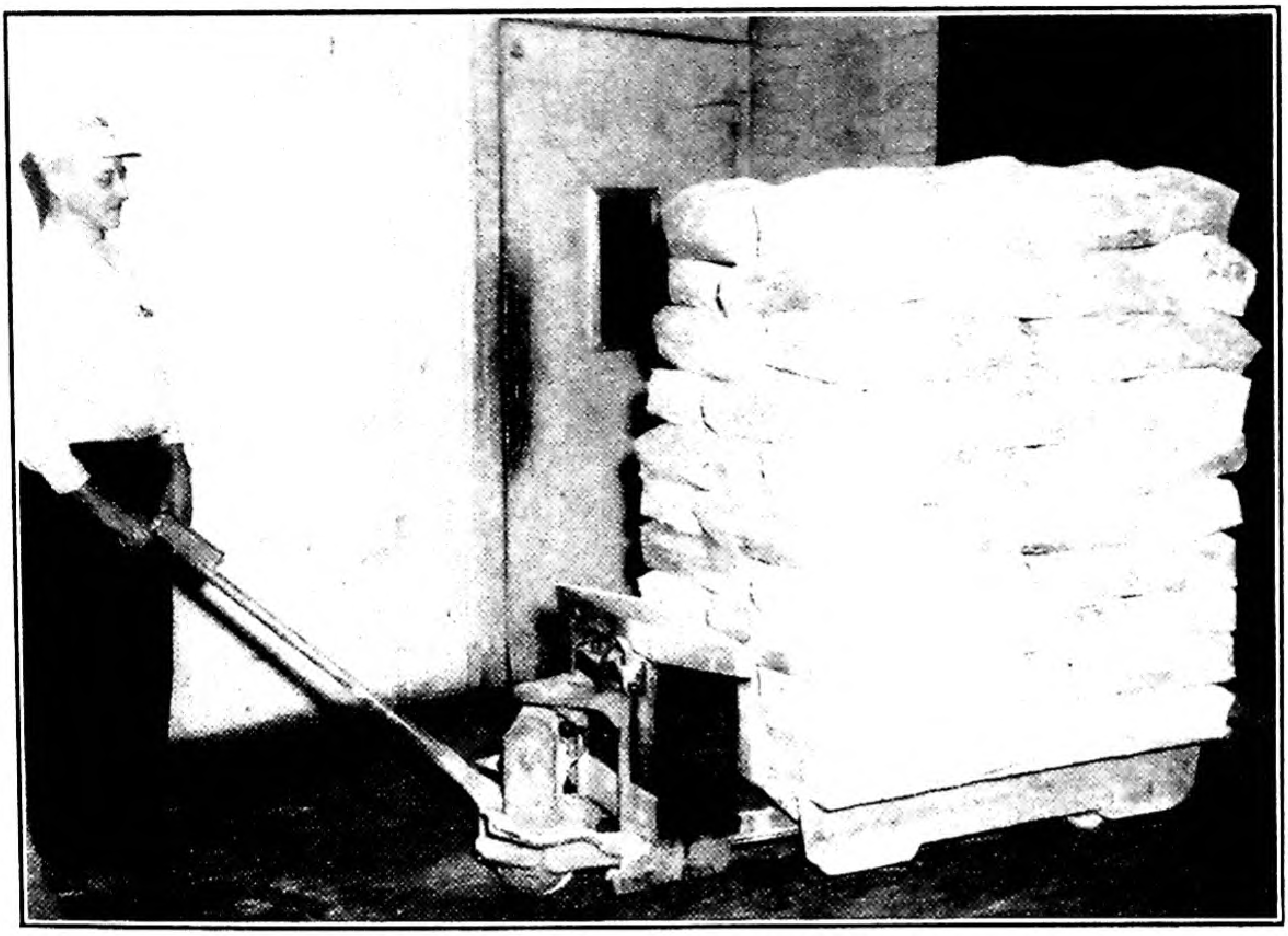


FIG. 1. Hand truck with pallet load.

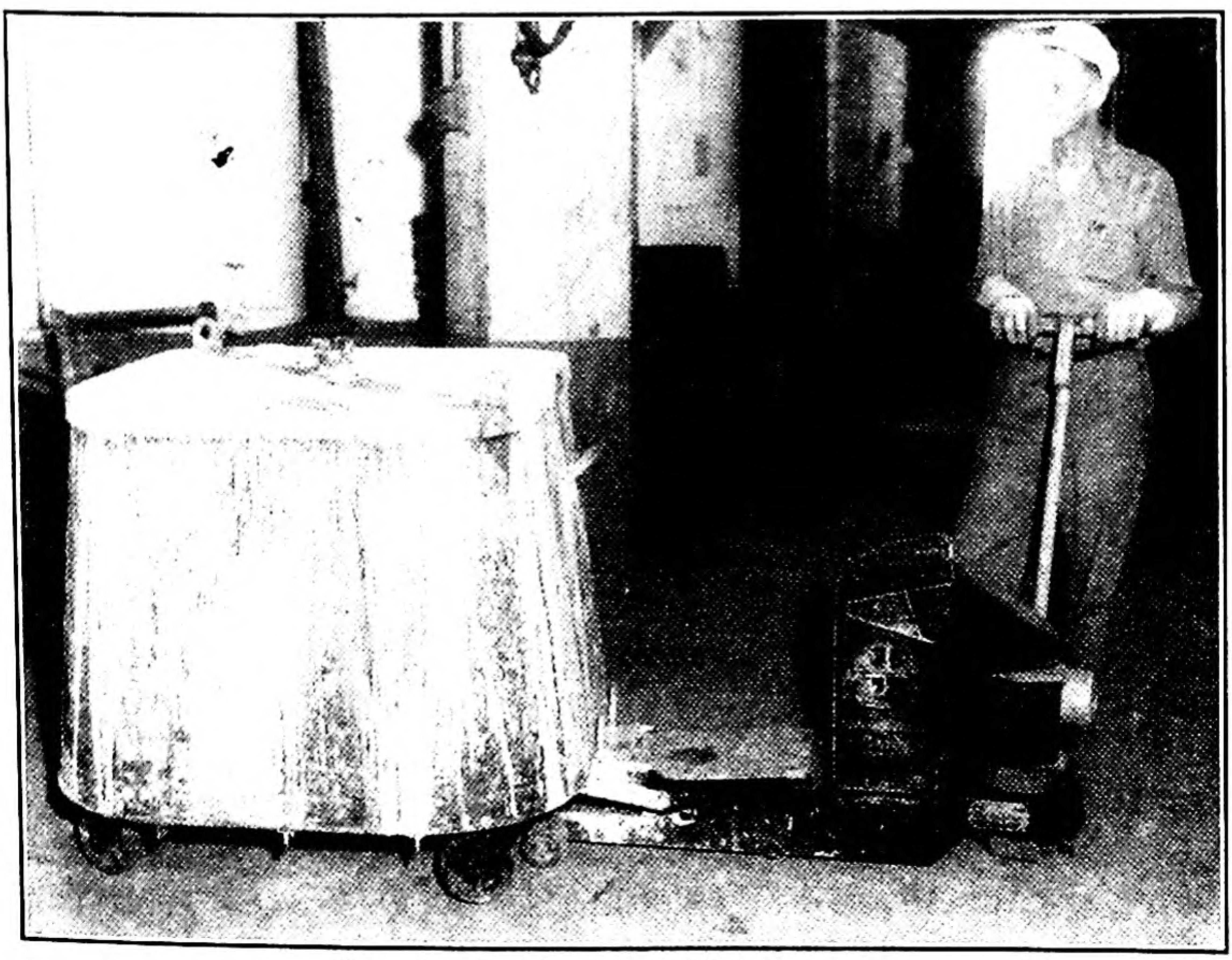


FIG. 2. Moving material in process.

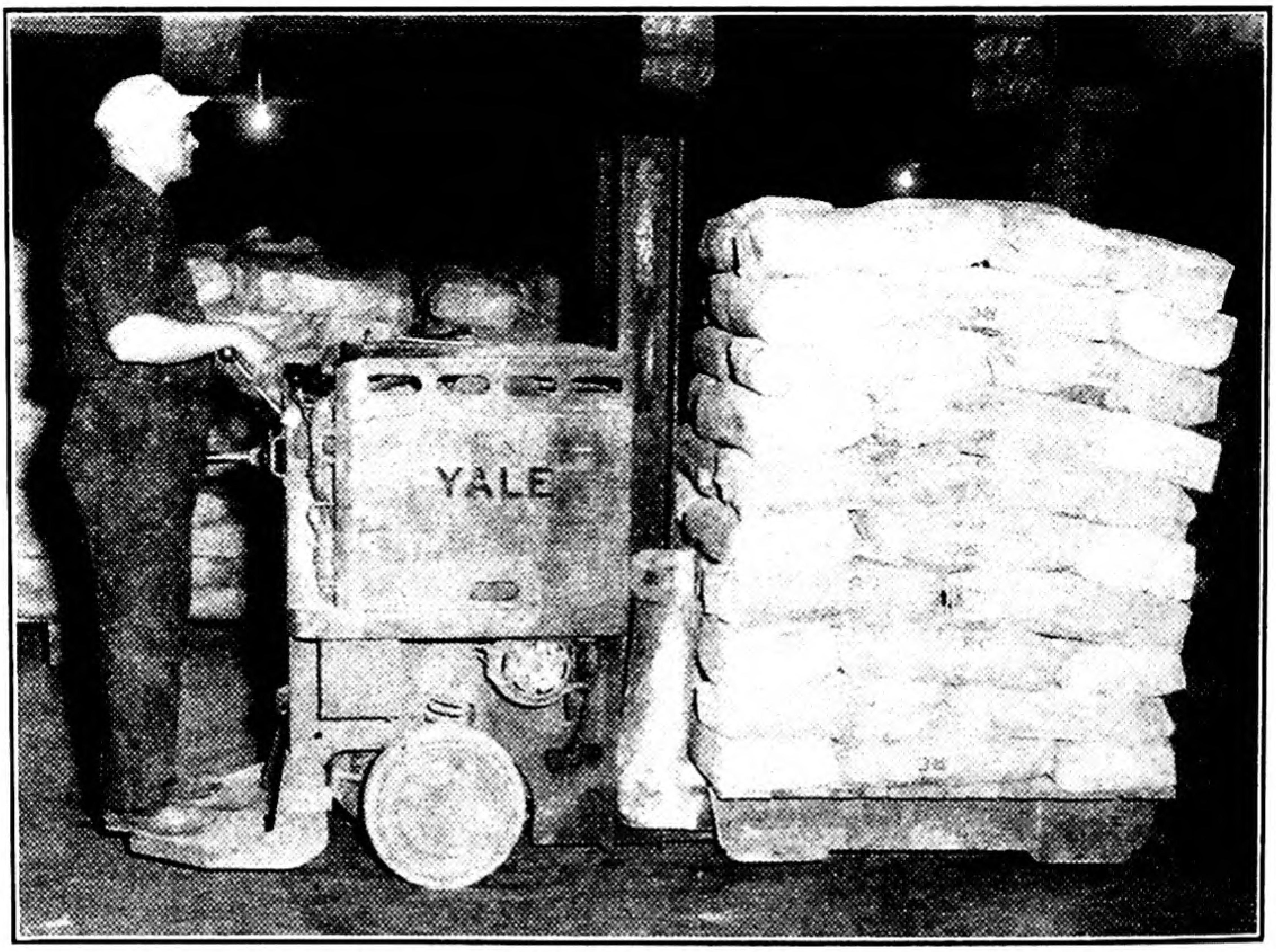


FIG. 3. Power-driven platform truck.

FIG. 4. Fork truck with skid load.

can come closer to the load, can turn in a shorter radius for a given wheel base, and can stack higher with pallets (rather than skids), dunnage usually being eliminated in stacking. For a given load, however, a fork truck is always heavier than a platform truck and more expensive. Where building construction will not permit the heavy weight concentration on the front wheels of a fork truck, a platform truck must necessarily be employed. Fork and platform trucks are often used in combination with other sorts of equipment, such as trailers.

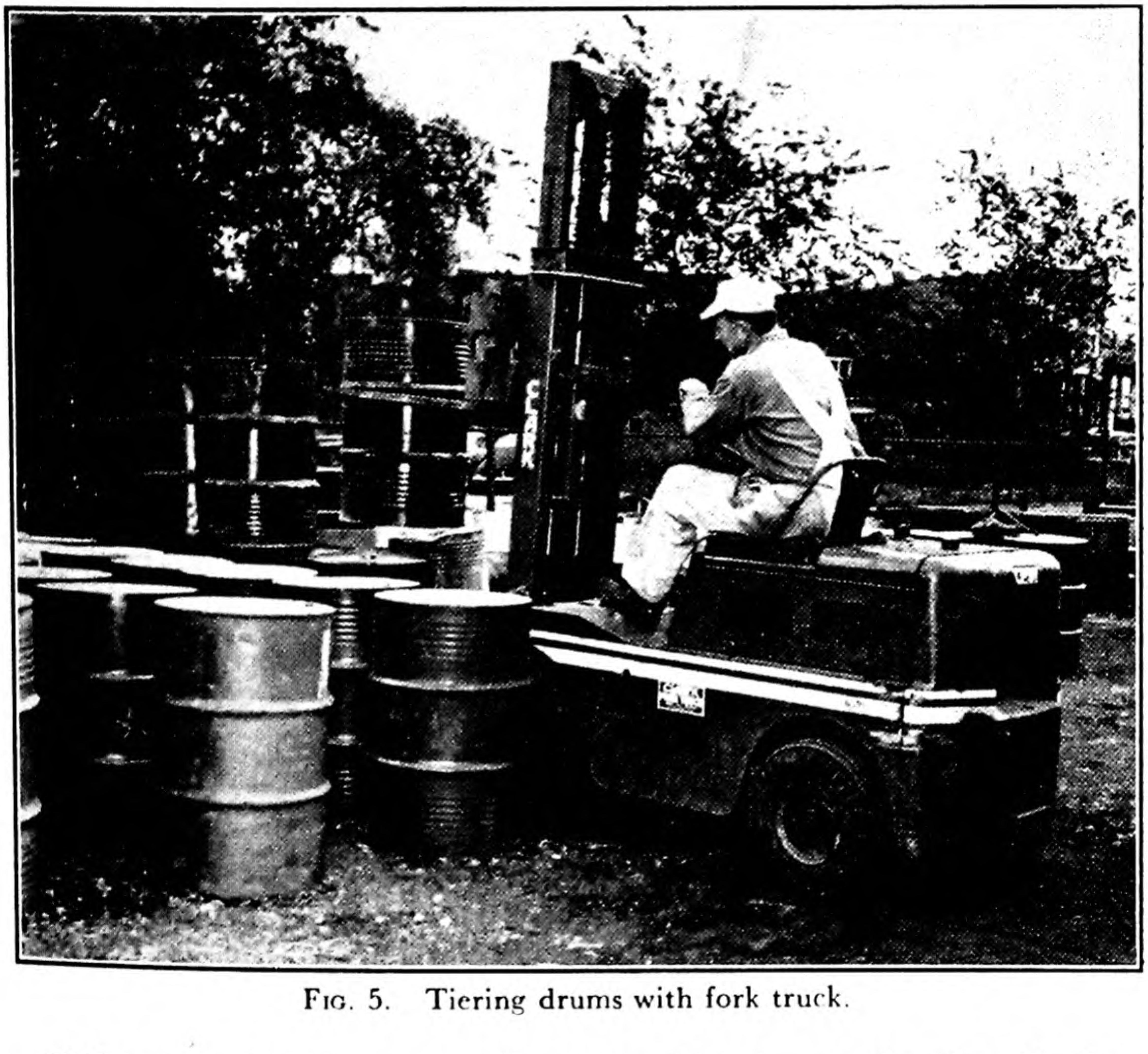


FIG. 5. Tiering drums with fork truck.

Pallets are almost as versatile as the fork trucks that handle them and are available in many designs of wood, metal, wire, and combinations of these materials. At present there is need for standardizing pallets in order to reduce the number of sizes, and also for reducing or eliminating the cost of pallet returns to the point of origin.

Industrial Tractors. Tractors and trailers, used for hauling loads between plants or widely separated departments, handle materials at less cost per ton than power trucks, but they lack the flexibility of the latter. Lower operating costs are obtained because the operator and his helper can handle a tractor with a train of from 4 to 12 trailers, each carrying

from ½ to 1½ tons or an average total of 8 tons, equivalent to 4 tons per man per haul. Tractors carry no load except the driver but are used to push or pull the load on trailer trucks. They are able to draw heavier tonnage than a carrier-type truck of equal capacity. Tractors can pull trailer loads up to 10 tons maximum at a speed of 5½ mph.

Trailers. Trailers are basically a development of the 4-wheel platform hand truck; but they are designed for greater strength and larger capacity in the transportation of dry materials and heavy bulk deliveries of liquids. Within practical limitations perfect trailing is possible, but trailers often creep, depending on the radius of turns, weight of loads, and condition of runways. In selecting trailers, the height of the platform from the roadway should be given consideration in order to eliminate excessive manual lifting.

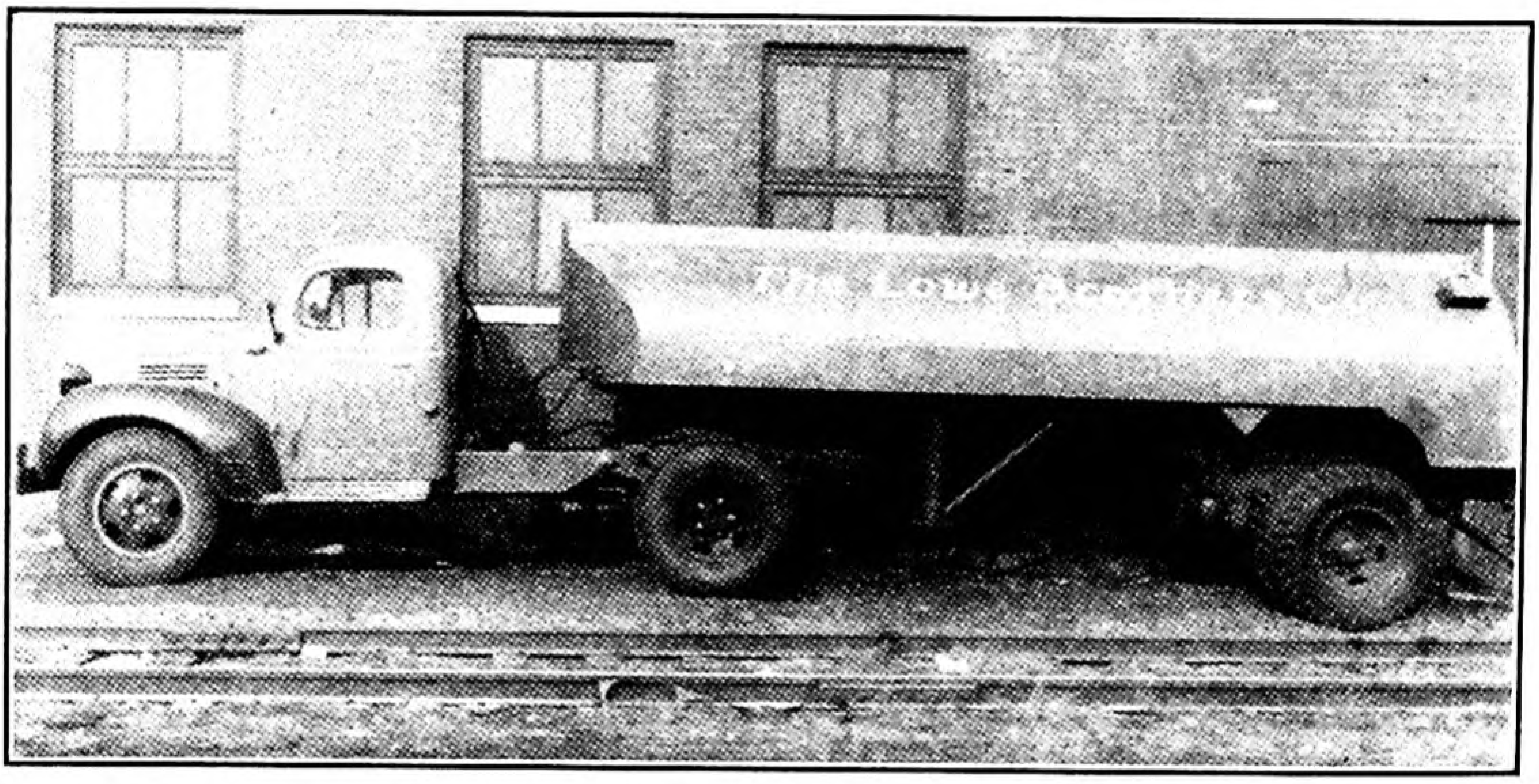


Fig. 6. Tank wagon trailer.

Conveyors and Hoists. In paint and varnish plants package-handling conveyors include a wide variety of equipment that is used in the continuous handling and transportation of case goods, pails, and drums. Because of limited space only the most important types will be considered.

Live-Roll Conveyors. Live-roll conveyors consist of a level gravity bed placed on supports or suspended from the ceiling, with a driving belt underneath and held in contact with it by means of pressure-roller sections. The belt is driven and motion is transmitted to the roller bed, causing packages to move forward. Materials can be transported continuously by this method over long distances, and the load can be stopped without causing undue friction under it.

Roller-Flight Conveyors. Roller flights are built with two strands of chain running in tracks with a series of cylindrical rollers mounted

between the chains at various centers, so as to form a continuous traveling bed. Conveyors of this type can be used where it is necessary to stop materials in transit without developing friction under the packages, because the rollers turn only when the load is not moving. During transportation, forward motion is maintained by the chains which are power driven.

Live-Belt Conveyors. Moving belts give smooth noiseless operation and can carry packages in opposite directions and divert them with ease. Fabric belts, which may be impregnated with rubber, or rubber belts are used to move loads as they travel over idlers at intervals. Belts operate more efficiently at high speeds than any other continuous carrier and can travel long distances with a moderate amount of power.

The generally accepted speed in package handling on belts is 100 fpm. Customary angles of inclination are 15°, but angles can be increased to 27° by using rough-surface rubber belts which will carry boxes and cartons at this angle without the use of cleats.

Gravity-Roll Conveyors. Conveyance by gravity is accomplished by a series of cylindrical rollers which revolve on ball or other free-running bearings and are mounted between the sides of a two-channel frame. The conveyors are made in standard sections with alternate ends, permitting quick and easy splicing of sections to any desired length. Lines can be permanent or changed conveniently to alter the direction for special or temporary service. These conveyors can be operated on a grade as low as 2 per cent with free ball-bearing rollers, although grades of 4 per cent and 8 per cent are customary. Attention should be given to the spacing of the rollers to afford sufficient bearing under the articles to be handled.

Gravity-Roll Spirals. Roll spirals follow the same principle as gravity-roll conveyors but are fabricated in spiral form and offer an economical method of lowering merchandise which requires care in handling. Packages can be lowered directly on the rollers, and pallets and trays permit successful handling of smaller objects. This type of equipment may provide temporary storage since packages will start or come to rest easily and evenly on the roller runway. Cartons may be allowed to back up on the spiral, and, as the lowest units are removed, the load will automatically travel downward.

Spiral Chutes. Friction spirals should not be confused with roller spirals. Both gravity and centrifugal force are involved when packages are impelled downward by gravity and outward by centrifugal action to produce a retarding effect. Spiral chutes are of three types: (1) closed-center chute, (2) open-center chute, and (3) open-center with post chute. This type of equipment has unusual capacity for handling packages that do not require special care.

Push-bar Elevators. Continuous motion conveyors or elevators may consist of two strands of chain with cross-bars mounted between chains at regular intervals and suspended above the carrying bed so as to contact the back of the package and push it up an incline. Definite advantages of this equipment are simplicity of operation, low initial cost, and automatic loading. Elevators are used extensively in gravity-conveyor systems as lifts between sections of gravity travel. They are suited for a more or less uniform range of packages and for practically any object of sufficient solidity and shape to slide on a runway. The angle of inclination is usually 60° to 70°, although they can be made to operate vertically. Capacities range from 500 to 1200 packages per hour at a chain speed of 60 to 90 fpm.

Monorail Chain Conveyors. Certain types of package-handling equipment permit overhead transport which relieves congestion in the flow of materials through the aisles of the plant and enables more effective utilization of floor space for storage. Monorail chain conveyors are important for this purpose and operate on the principle of an endless-circuit overhead monorail track, beneath which moves a power-driven chain connected at intervals to trolleys. The trolleys carry loads by means of hooks, racks, and similar devices, and the chain pulls them along. The line of travel may include right-angle and 180° bends when the travel is horizontal. They can also travel inclines up to 45° from the vertical, depending on the spacing of trolleys and loads carried.

Monorail Hoists and Telphers. Monorail hoists and telphers are similar in general design and usage and are often classified as identical machines. They are generally described as electric hoist mechanisms, cab-controlled, which are useful wherever necessary trackage can be installed for indoor or outdoor service. Such equipment is capable of handling heavy loads speedily between widely separated points.

Switches and turntables can be manually operated or electrically operated by remote control, so that a system can be installed either with a man riding in the cab behind the load or with the load suspended from power-propelled trolleys.

In many installations, electric hoists manually controlled from the floor will effect economies in loading to and from machine operations. When used in this manner over a limited area, they are sometimes known as monorail hoists. In general any of the following types of hoists can be operated in conjunction with monorail systems: (*a*) spur-geared hoists; (*b*) screw-geared or worm-edged chain hoists; (*c*) differential chain hoists; (*d*) pneumatic hoists; (*e*) electric motor hoists.

An efficient layout for storage purposes has been adopted in the Chicago plant of the Sherwin-Williams Company, as shown in Figure 7, which coordinates a variety of handling equipment with outstanding success. With belt, roller and drag-chain conveyors, fork lift trucks, tractor-trains, pallet-bearing trailers and semilive skids, 10,000 different items are moved in large units with the shortest possible travel and least possible handling. Cases and pails, arriving on the over-head conveyor from the factory, are not touched until they land at the pick-off stations, ready for palletization.

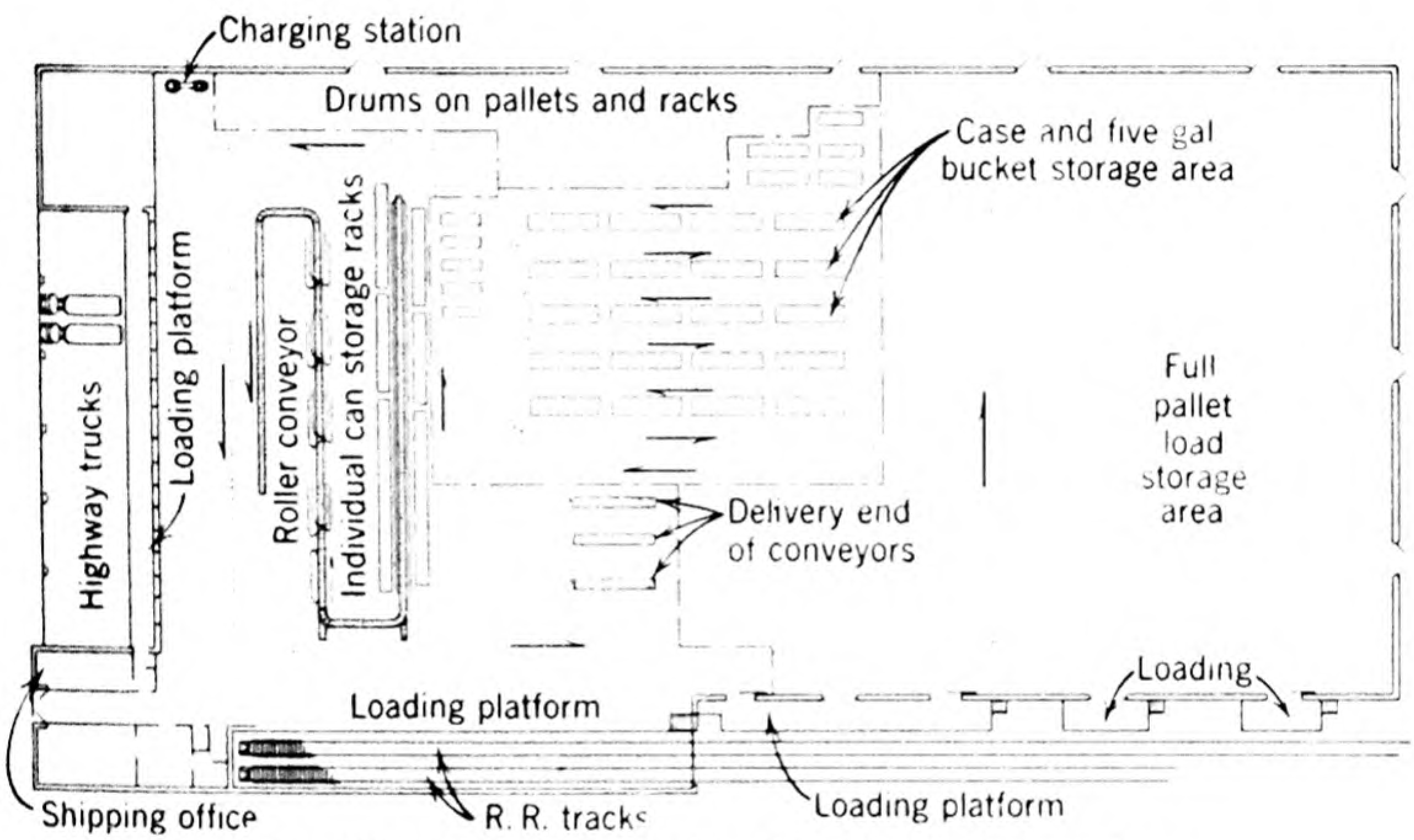


FIG. 7. Warehouse plan designed for maximum efficiency.

Pumps

For the purposes of this section, a pump is defined as any device employed for the transfer of liquids or pastes that flow readily.

Many types of pumps are available and are used, but the paint or varnish maker is principally interested in the major classifications known as centrifugal, rotary, and piston or reciprocating pumps.

Centrifugal Pumps. A centrifugal pump, in its simple form, involves an impeller rotating within a casing. The impeller consists of a number of blades, either open or shrouded, and is mounted on a shaft which projects outside the casing at each side.

This method of pumping is quite satisfactory for paints, varnishes, or solvents. Since it revolves very fast, a motor can usually be directly coupled to the shaft of the pump without the introduction of reducing gears or belt mechanisms.

The disadvantages of the centrifugal pump are: (1) precautions must

always be taken to prevent it from becoming "air bound," (2) it is not normally self-priming, and (3) it does not deliver a positive volumetric quantity under varying head or pressure. Owing to operating at high speeds, this pump is not suitable for handling paste products.

Rotary Pumps. Rotary and gear pumps can handle thin, heavy, or viscous liquids, develop high pressures, and give a discharge nearly free from pulsations. They can also deliver a positive quantity of liquid under conditions of varying head or pressure.

In a rotary-pump casing, two or more impellers are used in the form of tooth-gear wheels, helical gears, sliding vanes, or lobed cams. In each type the impellers rotate with very small clearances between each other and between the surface of the casing.

These pumps may be used for lacquers, solvents, varnishes, paints, and even fairly heavy pastes. In pumping paints or pastes, the pigments wear the pump through abrasion and periodic replacement of parts will be necessary, but, since the initial investment is low and the mechanics of replacement are simple, the cost of maintenance is very small per gallon of transferred material.

In order to handle pastes efficiently, suction lines and inlets should be large enough to ensure proper flow to the pump and the speed of the pump should be relatively slow. Clearances between impellers and casing also should be greater than for pumping low-viscosity liquids.

The versatility of certain rotary pumps is such that a single type of pump can perform practically all operations in a paint or varnish plant. The speeds employed will, of course, vary with each operation. The advantages in having common pumps and replacement parts are obvious.

When solvents are being transferred, pumps should be equipped with force-feed lubricators with suitable check valves between the lubricators and the pumps. Also, it is desirable to have pumps equipped with pressure-relief valves to prevent any injury to the pumps or motors.

Piston or Reciprocating Pumps. Piston or reciprocating pumps may be propelled by steam or electric power. In general, the transfer of materials is accomplished by a cylindrical piston, plunger, or bucket passing back and forth within a cylinder. The pump is equipped with valves for inlet and discharge, and their operation is directly related to the motions of the piston.

Before individual motor-driven units were available, steam-driven piston pumps were especially popular for pumping varnishes. The disadvantages of high maintenance costs, limited flexibility, and pulsating discharge have largely eliminated this pump in favor of the rotary type.

Pump Fittings. As indicated above, the pump selected may be either rotary, gear, or centrifugal, and in each it is desirable to have a steel

casing and the rotating element (except the shaft) of non-ferrous metal in order to reduce the hazards of static electricity. The shaft should be of steel or other suitable metal to withstand the wear encountered by moving parts.

As an alternative to the conventional stuffing boxes and glands in conjunction with force-feed lubricators, the pumps may be equipped with mechanical sealing devices. One seal of this type is known as Duraseal, and another is the Cameron seal, although others that are equally satisfactory are available. It is quite important that mechanical seals should be installed properly, because, if the work is improperly done, localized heating may result and the possibility of fire is encouraged.

The pumps should be located in a well-ventilated room, and the motors and controls should be explosionproof (specified as Class I, group D).

Discharge Pressures. The maximum permissible back pressure including discharge head and friction losses is, of course, a function of the individual pump and the size of its motor. In order to minimize leaks at valves and fittings and to avoid excessive maintenance, such as frequent packing of the pump proper, it is recommended that back pressures on thinners be held to a maximum of 50 psi, preferably 35 psi. For paints, varnishes, and oils, the back pressures should be held to a maximum of 200 psi, preferably 75 psi.

Pump Drives. In general, modern practice favors a direct-coupled motor or motor reducer to the pump proper. Other types of drives, such as open reduction gear, "V" belt, and flat belt with or without a clutch, may be used to give efficient operation. Direct drives are usually more quiet and require less maintenance.

Motor Horsepower. If the rate of discharge and the total pumping head are known, the power required to operate a pump can be computed. The theoretical horsepower is expressed by the following formula:

$$\text{hp} = \frac{\text{gpm} \times \text{h} \times \text{lb/gal}}{33{,}000}$$

where h = total head in feet of liquid.

Since pump efficiencies may range from 40 per cent to 65 per cent, depending on the pump and the conditions under which it is operating, power computed on the above formula must be increased in proportion.

Suction Lines. For proper operation of any pump, it is essential that the correct size of pipe be used for the suction side. The frictional head and the viscosity of the liquid must be considered, as well as the vertical lift, so that the total of all factors will not exceed the permissible maxi-

mum suction lift of the pump. Other conditions being equal, the lower the lift, the better the pump will operate.

The following general rules apply:

The suction line should be short and direct.

The suction line should be free of air pockets and air leaks.

Positive pressure on the suction side should be maintained if possible.

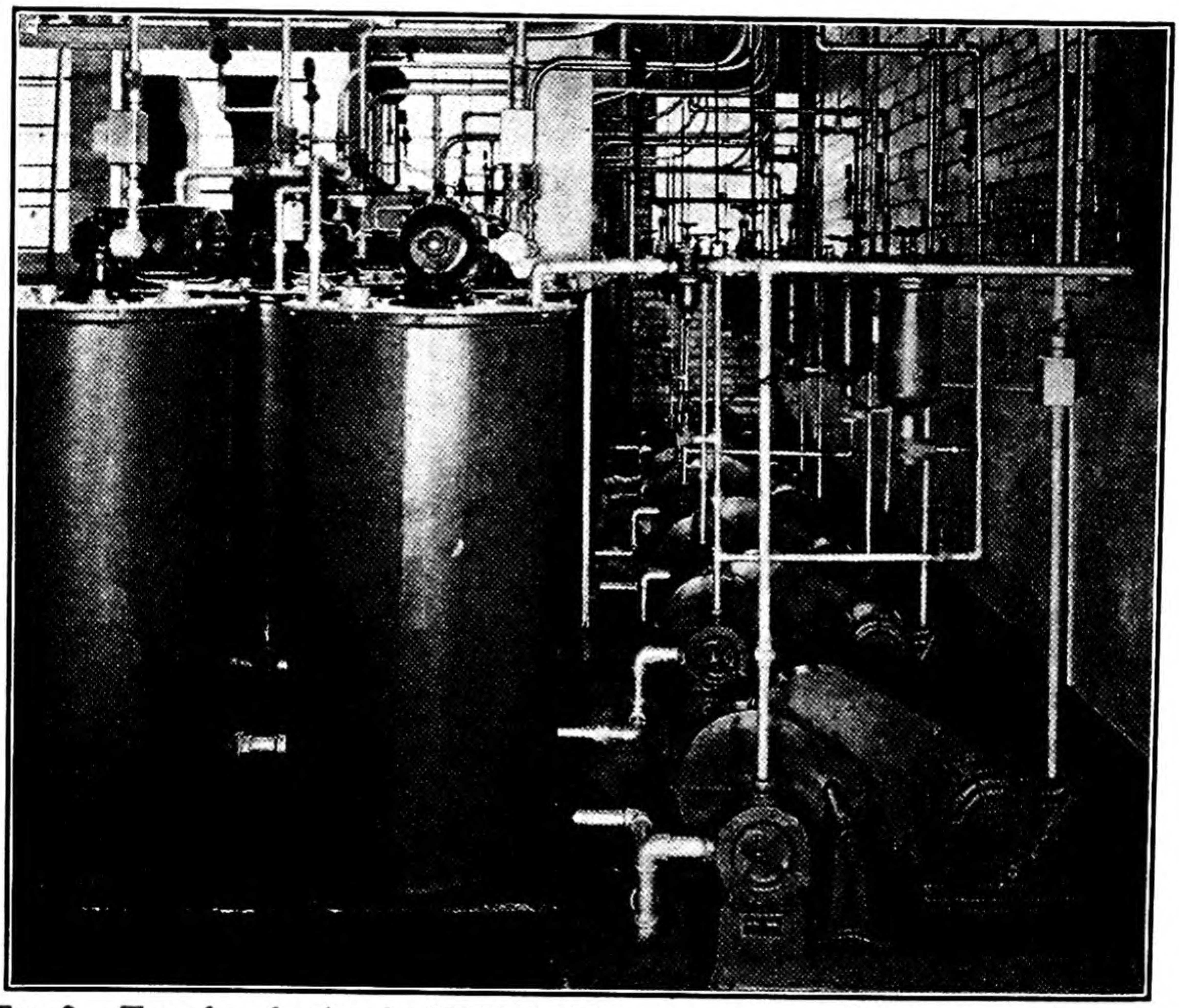


FIG. 8. Transfer of paints by "V" belt-driven pumps geared to deliver 5 to 8 gpm.

In those cases where the pump operates at a negative pressure on the suction side: horizontal elbows in the suction line should be at a lower elevation than the pump inlet; horizontal elbows should never be installed next to the pump, and, if possible, a vertical elbow should lead into the pipe reducer.

In permanent tanks, the end of the suction pipe should be at least 3 ft below the minimum pumping level of the liquid being transferred.

A strainer should be installed in the suction line to prevent foreign matter from entering the pump.

Pipe Lines

Flow Factors. In the majority of systems, any consideration of pumps involves selection of the proper-sized pipe lines. Such selection presumes a knowledge of frictional line losses which must be obtained either by computation or test. Often, computation is difficult or tedious, owing to the many factors involved. Likewise, it is often impractical to conduct tests that simulate actual operating conditions.

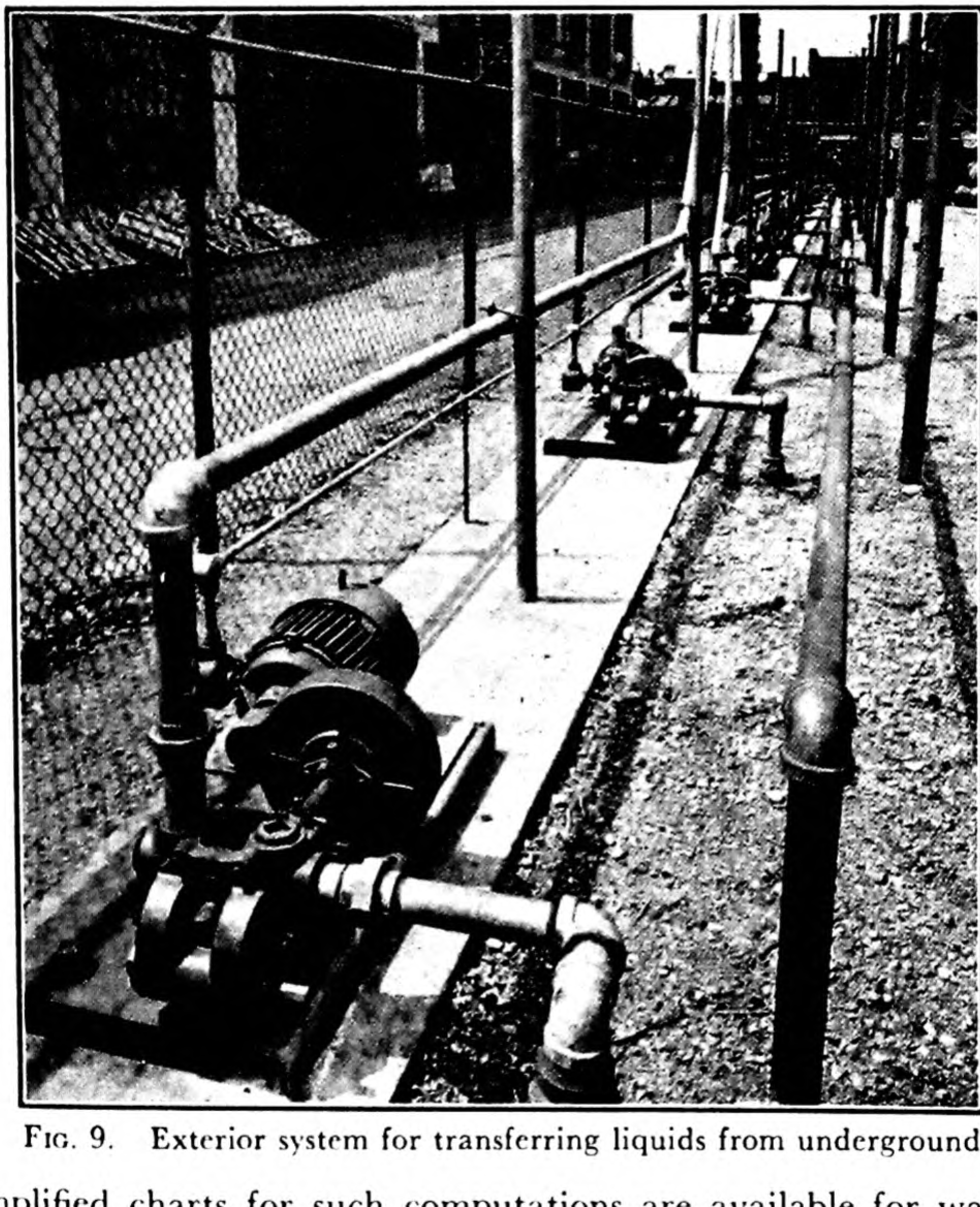


Fig. 9. Exterior system for transferring liquids from underground.

Simplified charts for such computations are available for water and petroleum products. In order that similar information may be available to the paint and varnish manufacturer, Table 1 has been prepared which includes the necessary data to solve the problems for most installations. With this chart and the information known about the liquid being pumped, the following estimates may be obtained: (1) size of pipe line; (2) frictional resistance of pipe line and fittings.

In addition, Table 2 illustrates power and speed requirements for a 2½-in. rotary gear pump. The speeds were chosen to correspond to

standard output speeds of gear-head motors which for this pump gave discharge rates of 81, 53, 44, and 29 gpm. Such output rates cover the normal range requirements.

Viscosity. Since the viscosity greatly affects the frictional resistance of the pipe line, it is important to know the viscosity of the liquid at the temperature when it is pumped. *The viscosity is also the determining*

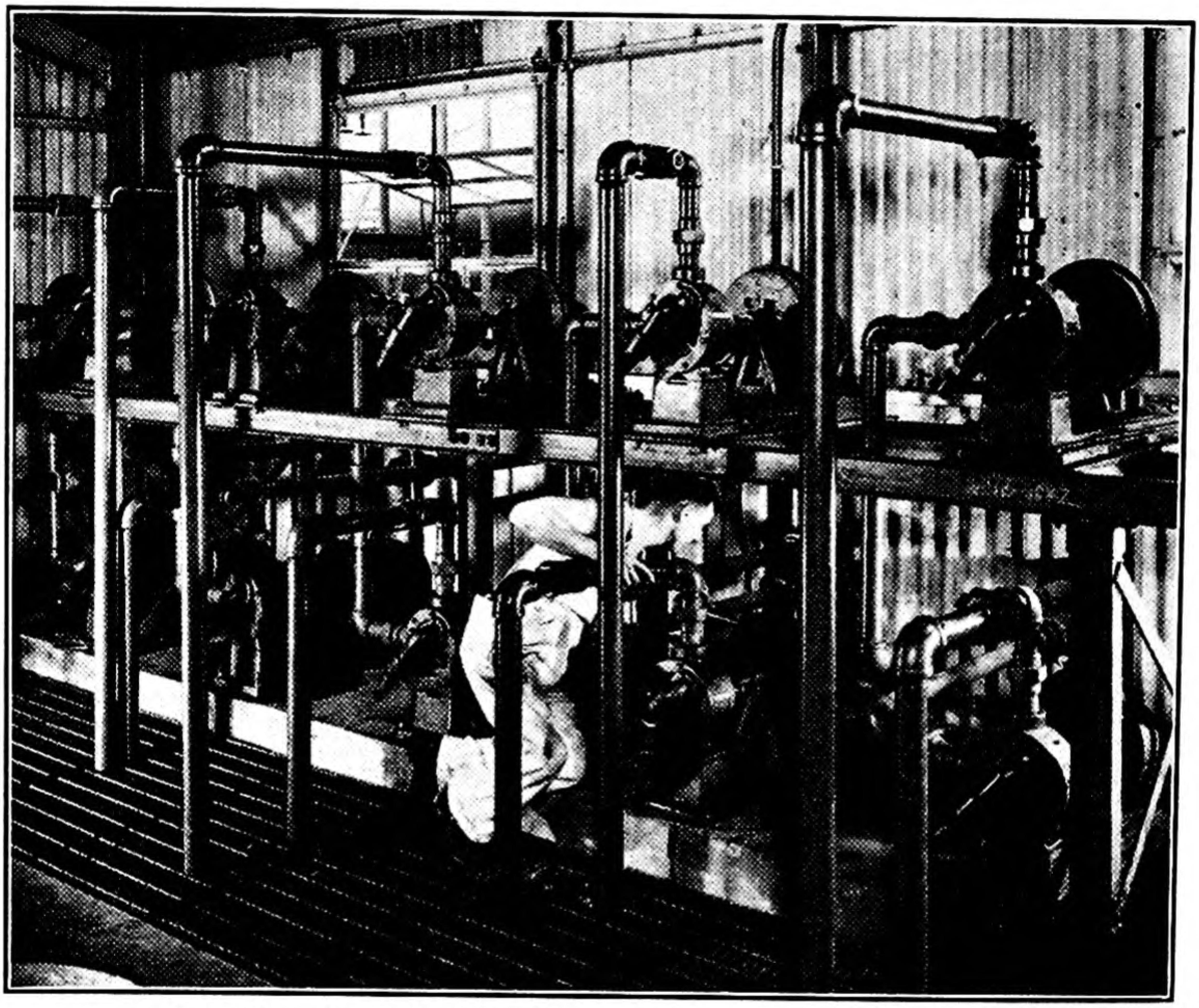


FIG. 10. Central system for pumping from remote storage.

factor for the speed at which a pump can be successfully operated. In pumping viscous liquids, it is advantageous to heat the liquid to a temperature that will reduce the viscosity to a range that can be pumped more readily. Table 3 and the accompanying graph may be used to determine the viscosity of a representative group of varnishes and oils at various temperatures. Similar curves can be developed for other liquids under consideration.

Suction Lift and Discharge Head. The total head on a pump is the sum of the discharge head, the suction lift (or head), and the frictional head loss in the pipe.

The discharge head is equal to the vertical distance (in feet) between

the center line of the pump shaft and the point of free discharge or the level of the free surface of the discharged liquid.

The suction lift is equal to the vertical distance between the center line of the pump shaft and the top surface of the liquid being pumped.

If the surface of the liquid is above the center line of the pump shaft, the suction lift is termed suction head.

Friction Head Loss. The frictional head may be very easily determined from Table 1 if the following data are available: rate of flow in gpm, size of pipe, the total length of pipe, the number and type of fittings and valves, specific gravity, and the viscosity of the liquid at the operating temperature.

Friction head loss due to fittings is usually figured with published data based on turbulent flow. This is not always a safe procedure with varnishes because the heavier types often move only under streamline conditions. In streamline flow, fitting losses vary with changing flow conditions. It has been found that viscosities exceeding 10 poises normally move only under such conditions that fitting losses become negligible. As viscosities drop, these losses increase until they reach accepted turbulent flow figures. Experience indicates that the approximations listed below Table 1 will be satisfactory for normal calculations.

Selection of Pipe Line Size. In deciding the size of pipe for any line installation it is advantageous to select a pipe of sufficient diameter to give a *friction head loss* of less than 150 ft (or 60 psi). Also, in adding the friction head loss to the *discharge head* to obtain the *total head,* the combined figure should not be more than 186 ft (or 75 psi). (See also Discharge Pressures page 15.)

Range. If the values for gpm and viscosity of the liquid are different from those shown in the tables, the head loss and pressure drop for any desired gpm can be interpolated. Since the tables give a wide range of viscosities, a figure near the vicosity of the liquid being considered can be selected. The blank spaces indicate impractical conditions. For instance, one would not attempt to pump a Z viscosity varnish through a 2-in. pipe line at 81 gpm. Paints and lacquers are included as well as thinners and varnishes. In general, the friction head loss for paints will fall in the second group of Table 1.

Pastes present a special problem but the majority of pastes can be handled by a 2½-in. pump slowed down to deliver approximately 15 gpm.

Computation and Discussion. In order to eliminate the necessity of referring to many tables and to compress the maximum amount of information conveniently, it is essential to confine rates of flow, size of lines, and other data to those most used in practice. For instance,

TABLE 1
Pressure Drop per Foot of Line
(In Feet of Head Loss)

		Gallons per Minute	81 gpm				53 gpm				44 gpm				29 gpm			
		Pipe Sizes	2″	2½″	3″	4″	2″	2½″	3″	4″	2″	2½″	3″	4″	2″	2½″	3″	4″
		Viscosity in Poises and Gardner-Holdt Scale	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss
Varnishes and Oils	Thinners	0.85 poise C Viscosity	0.254	0.120	0.053	0.017	0.162	0.078	0.035	0.012	0.138	0.059	0.028	0.009	0.088	0.044	0.018	0.006
	Lacquers and Paints	2.25 poises I Viscosity	0.635	0.319	0.134	0.044	0.393	0.198	0.085	0.030	0.335	0.153	0.069	0.023	0.207	0.108	0.046	0.016
		3.55 poises N–O Viscosity	1.018	0.483	0.207	0.065	0.636	0.316	0.139	0.042	0.531	0.245	0.111	0.035	0.346	0.173	0.078	0.023
		6.27 poises U Viscosity	1.840	0.917	0.381	0.136	1.175	0.594	0.254	0.085	1.014	0.457	0.207	0.069	0.646	0.325	0.138	0.046
		11.8 poises W–X Viscosity		1.500	0.635	0.207	1.960	0.984	0.416	0.138	1.675	0.772	0.347	0.115	1.060	0.540	0.230	0.081
		22.7 poises Z Viscosity			1.292	0.438		1.970	0.831	0.277		1.544	0.690	0.230	2.230	1.080	0.460	0.157
		46.3 poises Z3 Viscosity				0.865			1.615	0.577			1.385	0.462		2.160	0.925	0.323

Allowable back pressure for varnishes and similar liquids:

186′ = 75 psi (recommended)
500′ = 200 psi (absolute maximum)

If possible, choose a pipe size to keep the friction head loss below 150 feet (or 60 psi).

Suction lift should not exceed 12 ft head loss or 5 psi vacuum.

Allowable back pressure for thinners and similar liquids:

103′ = 35 psi (recommended)
148′ = 50 psi (absolute maximum)

To convert head of liquid to pressure, use the formula

Pressure (psi) = Head (in feet) × 0.433 × Specific gravity of the liquid.

Equivalent Fitting Resistance
(to be added to pipe length)

Viscosity, Poises	Below 1	1 to 6	Above 6
1 Elbow	7.0 ft	3.0 ft	1.0 ft
1 Tee	15.0 ft	7.0 ft	1.0 ft
1 Gate valve	1.5 ft	1.0 ft	1.0 ft

TABLE 2

PUMP AND HORSEPOWER CHART

Maximum Allowable Pressure Drop in Feet of Head Loss

Gallons per Minute	81 gpm (350 rpm)			53 gpm (230 rpm)		44 gpm (190 rpm)		29 gpm (125 rpm)		
Horsepower	3 hp	5 hp	7½ hp	3 hp	5 hp	3 hp	5 hp	3 hp	5 hp	7½ hp
Viscosity in Poises and Gardner-Holdt Scale	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss	Feet Head Loss
Up to 5.5 poises A5-T Viscosity	100	170	250	140	230	150	250			
6.27 to 22.7 poises U-Z Viscosity				140	230	150	250	230		
27.0 to 46.3 poises Z1-Z3 Viscosity						135	230	185	300	500

VISCOSITY-TEMPERATURE GRAPH

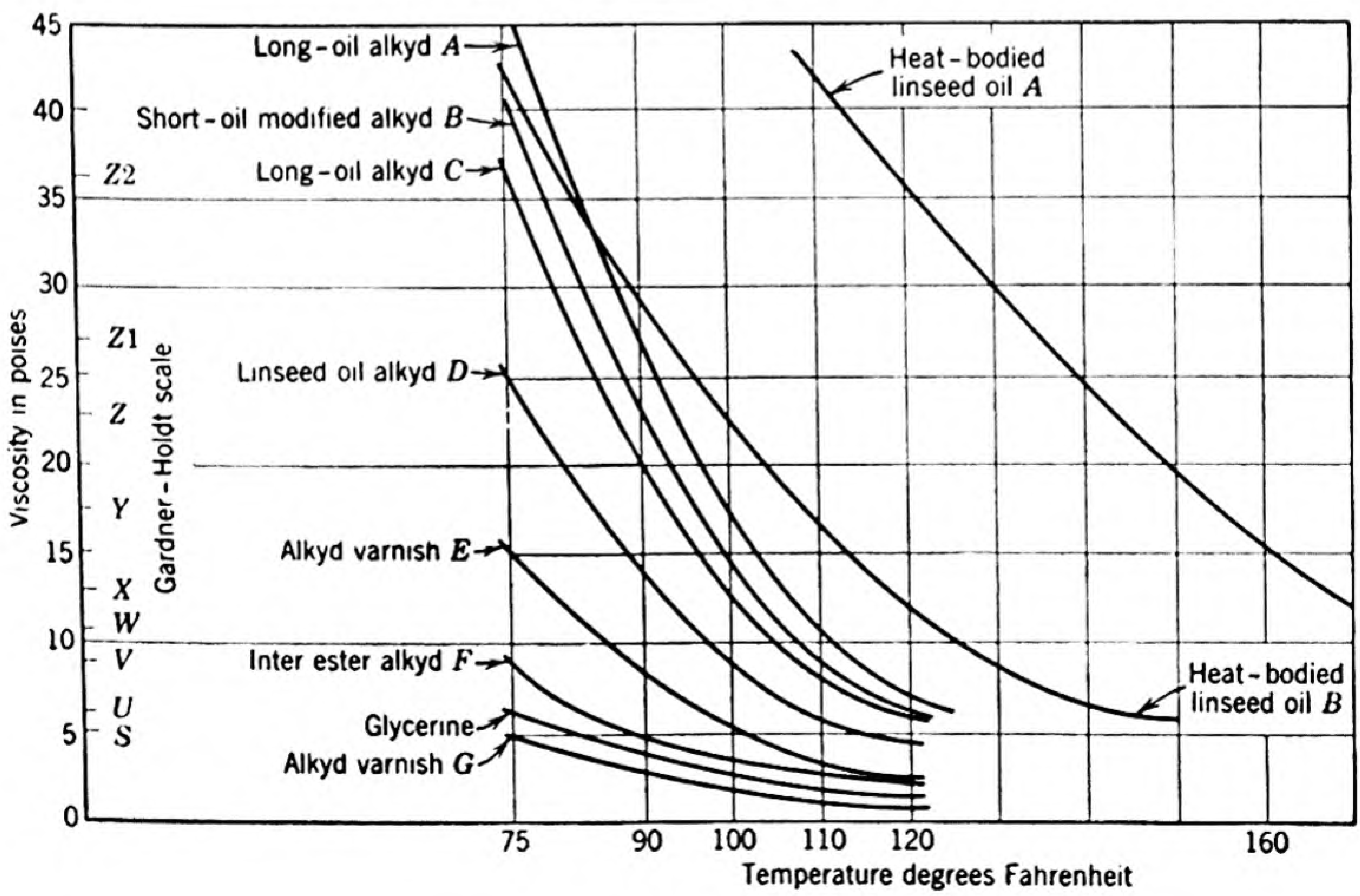


TABLE 3
Viscosity Conversion Table

Gardner-Holdt	Poises	Saybolt	Centi-stokes
A5	0.00505		
A4	0.0624		
A3	0.144		
A2	0.220		
A1	0.321		
A	0.50	230	50
B	0.65	298	65
C	0.85	388	85
D	1.00	456	100
E	1.25	568	125
F	1.40	636	140
G	1.65	750	165
H	2.00	909	200
I	2.25	1,023	225
J	2.50	1,136	250
K	2.75	1,250	275
L	3.00	1,364	300
M	3.20	1,455	320
N	3.40	1,545	340
O	3.70	1,682	370
P	4.00	1,818	400
Q	4.35	1,977	435
R	4.70	2,136	470
S	5.00	2,273	500
T	5.50	2,500	550
	Heavy Body Standards		
U	6.27	2,850	627
V	8.84	4,018	884
W	10.70	4,864	1,070
X	12.90	5,864	1,290
Y	17.60	8,000	1,760
Z	22.7	10,318	2,270
Z1	27.0	12,273	2,700
Z2	36.2	16,455	3,620
Z3	46.3	21,045	4,630
Z4	63.4	28,818	6,340
Z5	98.5	44,773	9,850
Z6	148.	67,273	14,800

thinners and low-viscosity varnishes are normally pumped at 80 to 90 gpm. Most high-viscosity varnishes are pumped at approximately 30 gpm. Tables 1 and 2 cover four definite rates of flow as well as pipeline sizes from 2 in. to 4 in., inclusive. Intermediate values can be determined by calculation.

Power figures are actual and not theoretical. Therefore, such factors

as pump efficiency have been included. Some applications may require less than 3 hp. However, pumps carrying less than 3 hp are limited in their application, and, because it is usually desirable to limit the number of models in stock for replacement purposes, Table 2 includes data for 3, 5, and 7½ hp motors only.

As indicated at the top of Table 1, the values given refer to pressure drop per lineal foot of line. The reason for expressing this in feet of liquid head loss (rather than in pounds per square inch) is to simplify the calculations. For instance, head loss expressed in this manner may be added directly to feet of elevation against which the liquid is to be pumped. The disadvantage in such terminology is the possible confusion when the phrase "liquid head loss in feet" is contracted to "feet." The lineal length of the pipe is also expressed in feet. Obviously, both these values are in different units. The first refers to a column of liquid which is a certain number of feet high. The second simply denotes the number of lineal feet in the pipe. When considering the problems which illustrate the use of the table, one must be careful to differentiate between these two values.

Illustrative Problem. *Problem I.* Find the frictional head loss in a 2 in.-pipe line which is to deliver 44 gpm of an I viscosity (2.25 poises) varnish (0.93 specific gravity). The line is 300 ft long and has 7 elbows and 2 valves.

The equivalent length of pipe is found as follows:

Actual length of line	=	300 lineal feet
7 elbows @ 3.0′	=	21 equivalent lineal feet
2 valves @ 1.0′	=	2 equivalent lineal feet
Total length of line	=	323 equivalent lineal feet

Refer to Table 1, group 2 (I viscosity) under 44 gpm.

Frictional head loss for 1 ft of 2 in.-pipe
@ 44 gpm = 0.335′ of head

Therefore,

$$\text{Total frictional head loss} = 0.335 \times 323' = 108'$$

Note: To convert this head loss of 108′ to psi pressure, use the formula given below:

$$\begin{aligned}\text{Pressure} &= \text{Head} \times 0.433 \times \text{Specific gravity}\\ &= 108' \times 0.433 \times 0.93\\ &= 43.5 \text{ psi}\end{aligned}$$

Problem II. Find the size of pipe line to deliver 81 gpm under the following conditions:

Viscosity of varnish	=	I (Gardner-Holdt) or 2.25 poises
Height to be pumped	=	40′
Length of pipe line	=	325′
Number of elbows in line	=	10
Number of valves in line	=	4

Also, find the size of motor required.

Since 1 elbow is equal to 3.0 ft of line and 1 valve is equal to 1.0 ft of line, the equivalent length of line is equal to the measured length of the line plus the equivalent length of the elbows and valves or

$$325 + (10 \times 3.0) + (4 \times 1.0) = 359 \text{ equiv. lineal feet}$$

The back pressure allowable is 186 ft of head. (See note at bottom of Table 1.)

$$\text{Total back pressure} = \text{Discharge head} + \text{Friction head loss}$$

Then,

$$186' = 40' + \text{Friction head loss}$$
$$\text{Friction head loss} = 186' - 40' = 146' \text{ of head}$$

Therefore,

$$\text{Friction head loss allowed per lineal equivalent foot of pipe} = \frac{146'}{359'} = 0.407'$$

From Table 1 under 81 gpm and I viscosity conditions we find that the friction head loss figure 0.407 ft per foot lies between a friction head loss of 0.635 ft per foot for a 2-in. pipe and a friction head loss of 0.319 ft per foot for a 2½-in. pipe. Since the friction head loss cannot exceed 0.407 ft per foot as computed above, the 2½-in. pipe size is selected.

Since 1 ft of 2½-in. pipe will give a friction head loss of 0.319 ft, the total friction loss in the 2½-in. pipe line is equal to 0.319 × 359 ft or 115 ft.

Since

$$\text{Total head} = \text{Friction head loss} + \text{Discharge head}$$
$$\text{Total head} = 115' + 40'$$
$$= 155'$$

From Table 2 under 81 gpm and for an I viscosity varnish we find that the total head loss figure 155 ft lies between 170 ft for a 5-hp motor and 100 ft for a 3-hp motor. Since the maximum head loss which the 3 hp is capable of pumping against is only 100 ft, it will be necessary to use a 5-hp motor.

In the above problem no attempt has been made to limit the friction load in the pipe line to 150 ft. If this had been done, it would have been necessary to use a 3-in. pipe line and in this case a 3-hp motor would have been sufficient. Therefore, it is suggested that each problem be computed both ways, neglecting the friction load limit of 150 ft in one case, and setting the maximum friction load loss at 150 ft in the second case. The pipe size and pump should, of course, be the combination which is most economical for the situation at hand.

Problem III. Determine the size of suction line for an installation to deliver 44 gpm of an I viscosity varnish. The suction lift is 8 ft. There are 3 elbows in the pipe line which is 30 ft long.

$$\begin{aligned} \text{Length of pipe} &= 30' \\ 3 \text{ elbows @ } 3.0' &= \underline{\ 9'\ } \\ \text{Equivalent length of line} &= 39' \end{aligned}$$

Since the maximum suction lift should not exceed 12 ft, the difference between 12 ft and the given suction lift divided by the equivalent length of line equals the maximum friction head loss per foot of line permissible or

$$\frac{\text{Allowable suction lift} - \text{Suction lift in line}}{\text{Equivalent length of line}} = \frac{12 - 8}{39} = 0.103'$$

From Table 1 under 44 gpm for I viscosity we find that the friction head loss figure 0.103 comes between 0.153 for a 2½-in. pipe and 0.069 for a 3-in. pipe.

Since the maximum allowable friction head loss in the line is 0.103′ per foot of line as computed above, the 3-in. pipe which will give a maximum friction head loss of only 0.069′ per foot of pipe line is selected and the total suction lift will be equivalent to $8' + (0.069 \times 39')$ or 10.7 ft.

Operating Information.* Assuming that the pumping mechanism is properly designed and constructed to suit the specific conditions, the following suggestions may be applied to the operation of centrifugal or rotary pumps and can be used to analyze operating difficulties.

Pump Fails to Prime.

Pump has not received its initial prime.

Direction of rotation is wrong.

Strainer in suction line is clogged.

Leaks in the suction line are in excess of pump's air capacity under the existing conditions of vacuum. This may be detected by the two following methods: (1) Submerge the end of the discharge line in water. The presence of bubbles indicates the pumping of air. (2) Remove the suction line from the pump and install a blind flange on the pump inlet. Connect a vacuum gauge to the suction side of the pump and note if the dry vacuum pulled is ample for the suction lift required. If this is not sufficient and air continues to be discharged, there is an air leak in the pump. If the vacuum is satisfactory and little or no air is discharged after the maximum vacuum reading, the suction line is probably not tight.

Suction lift is too high for handling the desired material. The principal factors involved are as follows: (1) Specific gravity of the liquid is too high. The possible height of suction lift varies inversely with the specific gravity of the liquid. The only remedy is to place the pump closer to the liquid level. (2) The liquid under vacuum is vaporized, or absorbed gas under vacuum is liberated.

Pump Operates at Less That Rated Capacity.

By-pass is set too low and liquid is by-passed.

and liquid is by-passed.

Speed is too slow.

Suction lift is too high. With hot or volatile liquids there should be ample suction head.

Screen or suction line is clogged or by-pass spring may be clogged.

* L. M. Barish, third item under *Official Digest Bibliography.*

Pump is damaged or badly worn.

Suction head is lost due to air leaks in suction piping or the pump stuffing gland.

Foot valve is too small or obstructed.

Suction line is not immersed deeply enough.

Piping is improperly installed, permitting the formation of air or gas pockets.

Variation in the Rated Pump Capacity.

Suction lift may be too high.

Air leaks have occurred in the suction piping or the pump stuffing gland.

Air or gas is trapped in the liquid.

Pump Requires an Increase in Power.

Speed is too high.

Suction or discharge line is clogged.

Liquid is heavier or more viscous than specified.

Pump stuffing glands are too tight.

Pump shaft may be bent.

Misalignment may have been caused by mounting pump base on an uneven surface.

Misalignment may have developed from the load of the pipe and connections.

Pump Becomes Noisy.

Suction and discharge pressures may be too high.

Air leaks may have developed in the suction piping or the pump stuffing gland.

Air or gas is trapped in the liquid.

Suction velocity is too high, and too many changes in direction of the suction line are indicated.

Heat, Light, and Power

The demands of the paint and varnish industry for these three essential utilities and services follow the general pattern of all industrial plants, and only those features which specifically apply to the industry will be presented.

Heat. Low-pressure heating systems with overhead blower-type radiators and directional vanes or floor-type radiators with ductwork to distribute the heat overhead are most satisfactory because of automatic control and the elimination of licensed engineers and supervision.

Although the industry as a whole has made no attempt to air-condition its operations, precautions to eliminate fumes and dust are common in many plants. It is generally acknowledged that the laboratory should

be the first to benefit from controlled conditions, with some consideration given to mixing and grinding operations. If it is impractical to standardize entirely, at least one room should be maintained at a constant temperature of 77°F with 50 per cent relative humidity for laboratory testing purposes.

The best working conditions in the various production departments will range from 65° to 70°F with 50 per cent relative humidity, depending on the activity of the labor involved.

For the storage of oils, varnishes, and viscous liquids over long periods of time, an average temperature of 80°F is desirable. Provision for warm storage of heavy-bodied items during the winter months will not only speed up the dispensing of these liquids from tanks and drums but prevent precipitation or flocculation of seedy materials in many vehicles which are sensitive to low temperatures. An insulated room where the temperature can be maintained at about 125°F is useful for intermittent storage to speed up the transfer of heavy-bodied materials from drums and to reduce losses caused by incomplete drainage.

Finished goods should be stored in a dry atmosphere with the temperature approximately 70°F. Under these conditions, and when cans have been properly filled, labeled, and cartoned for storage before shipment, difficulties, such as rusting, bulging, leaking, loose labels, and generally defective packages will not develop.

Light. Although the lighting requirements for most operations in the manufacture of paint products are not so exacting as for the close precision work of many industries, adequate lighting is essential to avoid errors and employee fatigue.

It is suggested that the plant engineer rely on foot-candle readings to determine accurately the kind and amount of artificial light required.

The following figures in foot-candles will serve as a guide for proper illumination in the various departments: mixing, 30; grinding and thinning, 30; tinting, 200; filling and labeling, 30; storage and shipping, 10; offices and laboratories, 50.

Operators agree that the best source of light for tinting and shading of pigmented products is north daylight and, where artificial light must be used, a fluorescent or daylight lamp is recommended.

Not all the manufacturing processes of the paint industry present hazards which require explosionproof or vaporproof fixtures, but where inflammable fumes are concentrated such provision is mandatory.

To avoid any possibility of exceptions or violations which may contribute to danger through error or neglect, some plant managers demand an explosionproof or vaporproof system of lighting for all operations.

From a safety viewpoint, until vaporproof units have been developed and are available, fluorescent lighting must be restricted to departments in which no hazard exists.

The publications of the Illuminating Engineering Society, American Standards Association, and the National Safety Council should be consulted for detailed information on the subject of illumination.

Power. In new plants and where there is a choice, the general opinion of factory management tends to prefer 440-volt circuits as the source of power, rather than the customary 220 voltage.

The higher voltage is especially recommended for heavy mixing and grinding machinery when the total demand exceeds 150 kw and when the operations are spread over a large area or in separated buildings.

Many plants are equipped with machinery, such as mixers, thinning tanks, and ball or pebble mills which are propelled by shaft and pulleys, but the trend in new installations is toward direct gear or V-belt drives for practically all equipment. The initial cost and ease of maintenance characteristic of V-belt drives ordinarily favor this type of transmission wherever it is adaptable, rather than the heavier installations required for gear-driven machinery.

Individually motorized units possess economical advantages over shaft and pulley systems for operating machines intermittently in batch processing. However, the shaft drive for batteries of ball or pebble mills can be very efficient if the loading, operating, and unloading of all mills can be handled simultaneously.

Owing to the nature of the paint business and the presence of inflammable vapors which under certain conditions may form explosive mixtures, it is desirable to consider explosionproof motors for all manufacturing departments.

Explosionproof switches are usually segregated in a fireproof room, or, under less hazardous conditions, vaporproof switches may be placed 10 ft from the machines controlled.

The operating devices which will include stop-start and/or jog buttons (for ball and pebble mills) should be installed in convenient locations near the equipment that they control and where they will be easily accessible to the operators.

In general, to make the power system flexible spare outlets should be provided at power distribution points. Power consumption should be supervised and can be reduced through the study of peak demand for sustained intervals and the staggering of the active loads accordingly. Installations which employ the principle of fluid transmission may permit the use of smaller motors and thus reduce the peak power requirements involved in the operation of many types of heavy machinery.

ACKNOWLEDGMENT

The editors express their appreciation to J. R. Kohr and A. Barkman of the Sherwin-Williams Company for much of the information contained in this chapter on the subjects of Materials Handling and Pumps and Pipelines, respectively.

The illustrations which have been furnished by the Blaw Knox Division, Brighton Copper Works, Clark Equipment Company, Eclipse Fuel Engineering Company, Massachusetts Engineering Company, Union Iron Works, Viking Pump Company, and others that have been reproduced throughout the Manual from prior publications by permission are gratefully acknowledged.

REFERENCES

Cameron Pump Operator's Data, Ingersoll-Rand.
Chemical Engineering Handbook, J. H. Perry.
Safety in Lacquer Plants, C. L. Jones, Hercules Powder Company.

OFFICIAL DIGEST BIBLIOGRAPHY

Atherton, C. A., "Lighting and Painting," p. 82 (Mar., 1943).
Aude, R. M., "Basic Principles of Materials Handling," p. 1012 (Dec., 1948).
Barish, L. M., "Pumps for Transferring Liquids in the Paint and Varnish Industry," p. 537 (July, 1948).
Bidlack, V. C., "Production Methods and Materials Handling," p. 208 (May, 1946).
Graff, W. M., "Use of Oil as Boiler Fuel," p. 4 (Feb., 1925).
Hoffman, E. E., "Management and the Task of Engineering Plant Modernization," p. 215 (May, 1946).
Mathews, J., "Materials Handling," p. 523 (July, 1950).
Preis, C. G., "Remodeling a Plant to Increase Efficiency," p. 44 (Feb., 1933).
Rice, W. W., "Developments in the Production and Use of Power," p. 5 (Feb., 1924).

CHAPTER 2

PAINT PLANT

Any choice of plans for the flow of production in a paint plant must take into consideration the facilities which can be made available for the handling of materials as discussed in the previous chapter. The storage of raw materials, the movement of products in process, and the warehousing of finished goods all require physical effort. A plant which avoids cross-traffic and congestion and employs mechanical

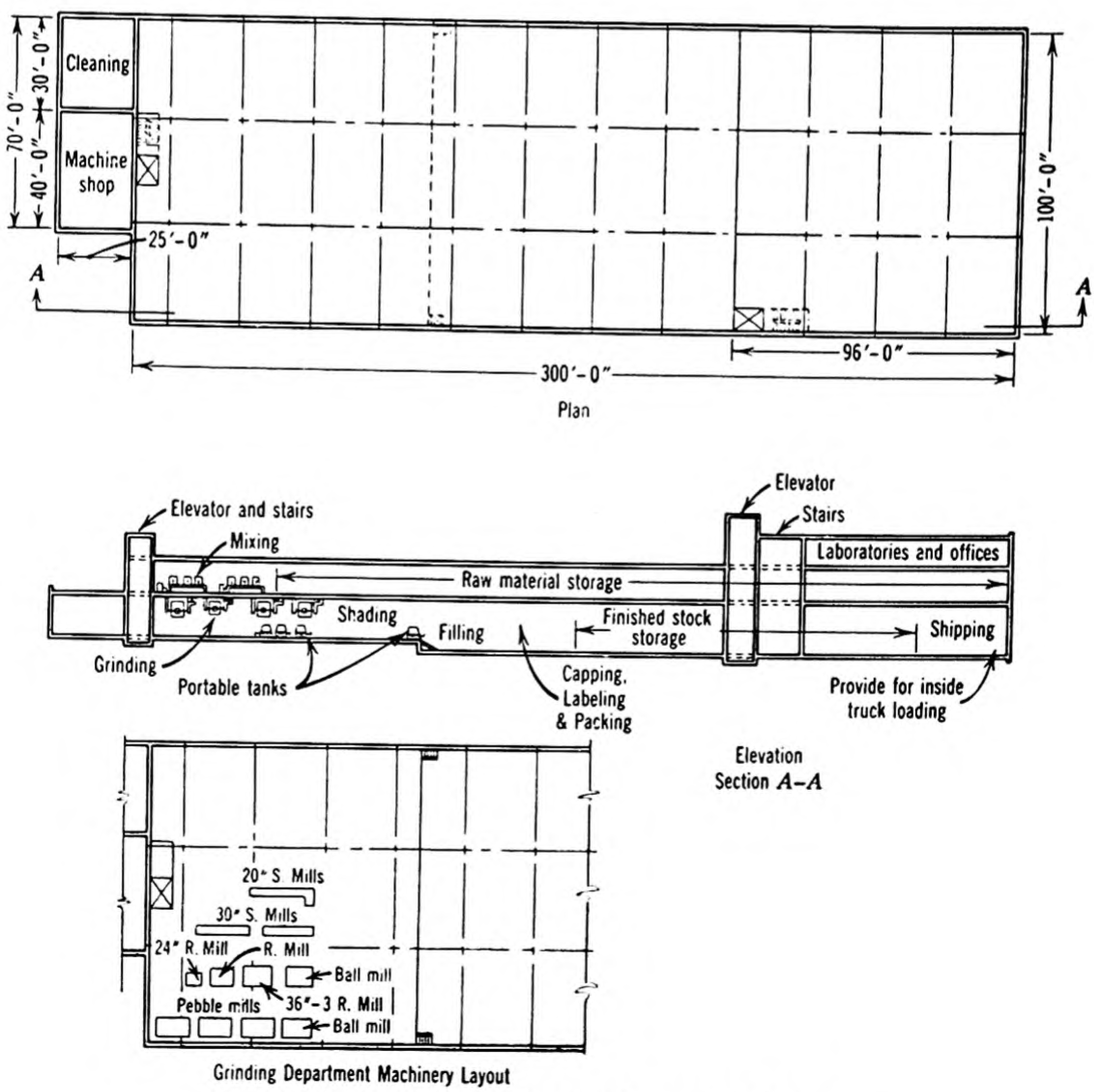


FIG. 11. Plan A. Horizontal flow production.

methods of transfer from one department to another will be the most efficient for housing all of these operations.

Examples of horizontal and vertical flow production shown in this chapter include engineering features that have been adopted by the paint industry for the manufacture of its products.

Horizontal Flow

Illustrated in the drawing identified as Plan A (Figure 11) is a plant occupying a ground area 100 ft wide × 325 ft long and designed for efficient production by the horizontal flow system. These dimensions are subject to change and may be increased or decreased according to the production requirements.

Provision has been made for laboratory and offices on a small third floor, with raw-material storage occupying most of the second floor adjacent to equipment for primary mixing. Mezzanine floors, which eliminate the need for a complete second floor, are often used to good advantage for this part of the operations. Grinding and shading departments are located under the mixers to utilize gravity flow before the materials in process resume horizontal flow to departments for filling, capping, labeling, and packaging, in that order. Finished goods are then moved into storage on the same level with shipping facilities located at the end of the building that houses the laboratory and general offices. This layout is flexible and affords versatility in production with the minimum of mill equipment.

Plan A closely approaches the ideal for horizontal flow production and can be readily adapted to the demands of a small or medium-sized plant.

Vertical Flow

Plan B illustrates the general scheme of a three-story plant designed for vertical flow production with overall dimensions of 225 ft × 314 ft.

Briefly, the manufacturing section of the plant provides for laboratory space and mixing operations on the third floor, grinding and processing on the second floor, with shading, thinning, filling, and labeling on the ground floor. Adjacent to the main building is a single-story warehouse 150 feet × 225 feet with dining room and lockers occupying a small portion of the space. Sales and administrative offices are located in a separate structure of two floors adjoining the warehouse.

Plan C (Figure 13) is the result of a cooperative study of plant layout by the Montreal Paint and Varnish Production Club and has been carefully worked out for the vertical flow of production for a general line of pigmented products with an output of 1500 gal to 2400 gal per day,

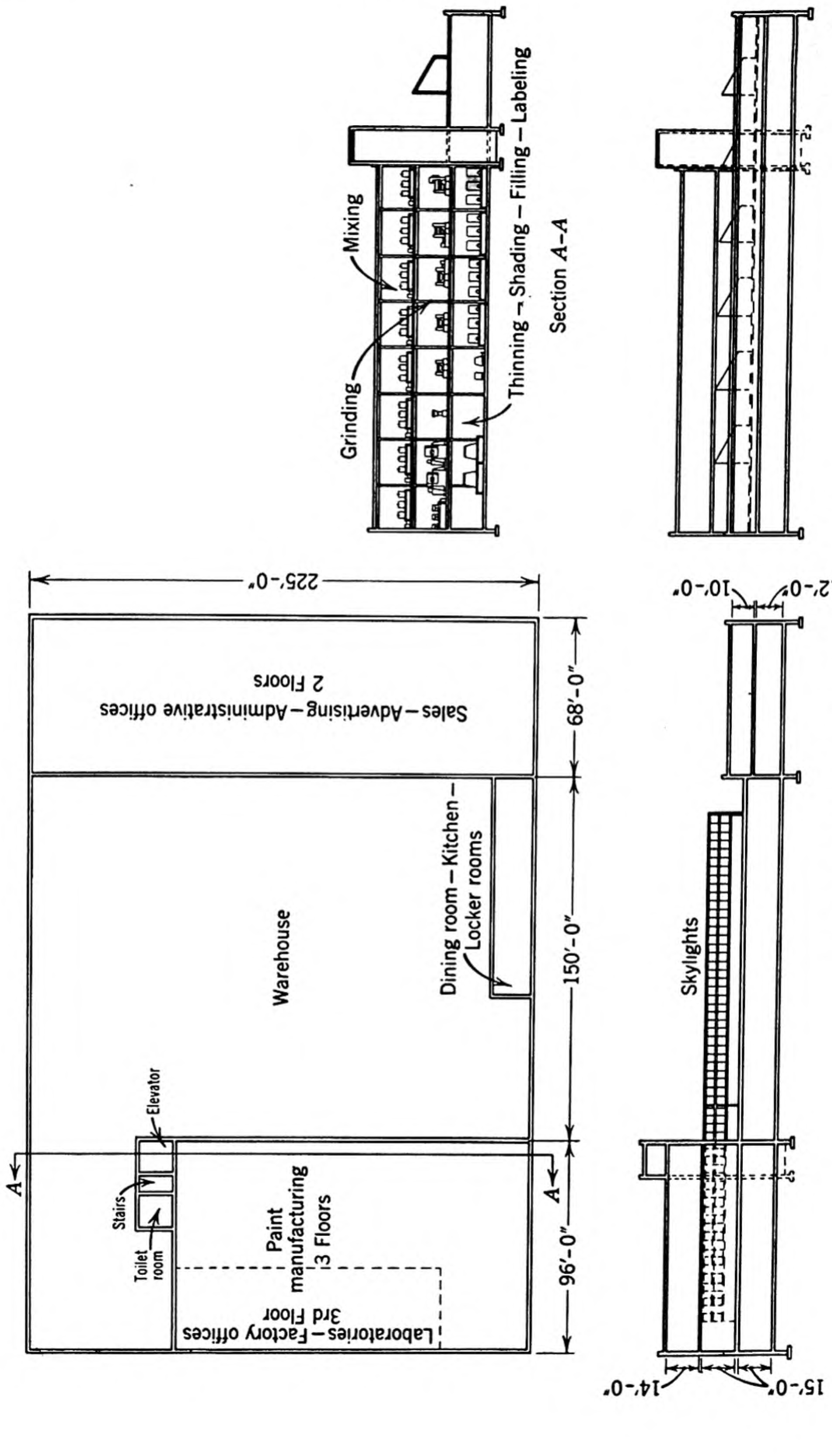


FIG. 12. Plan B. Vertical flow production.

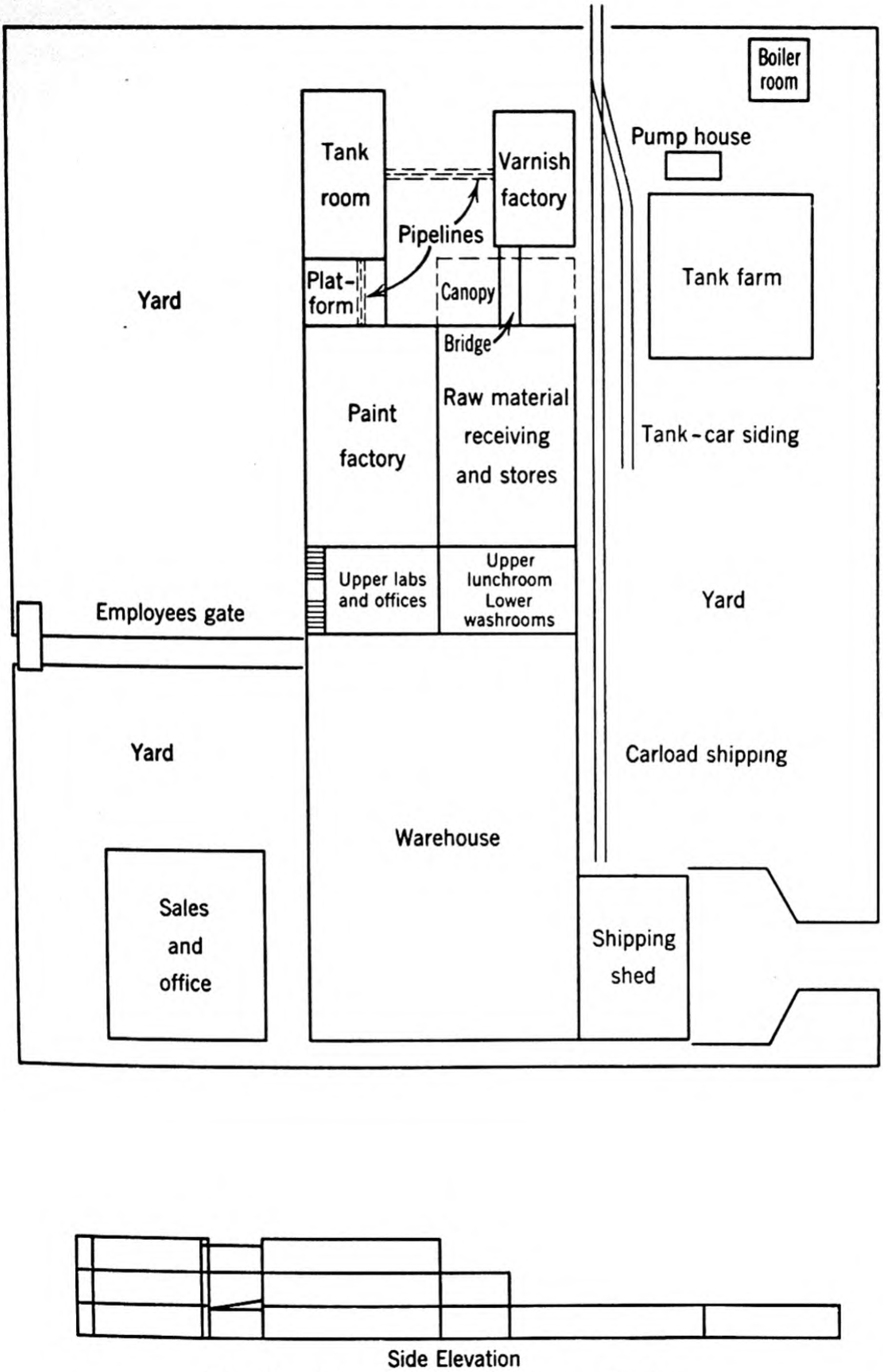
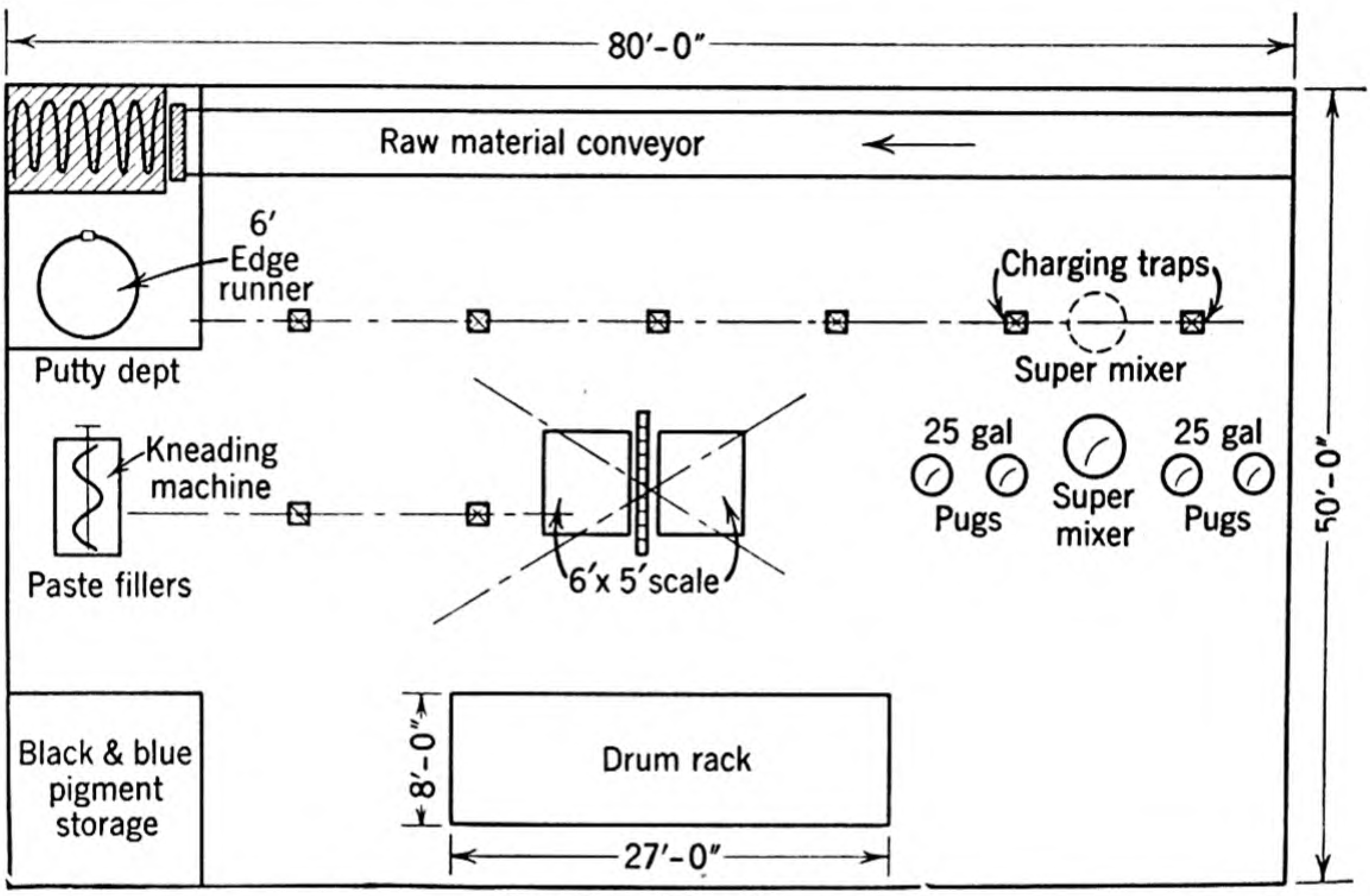


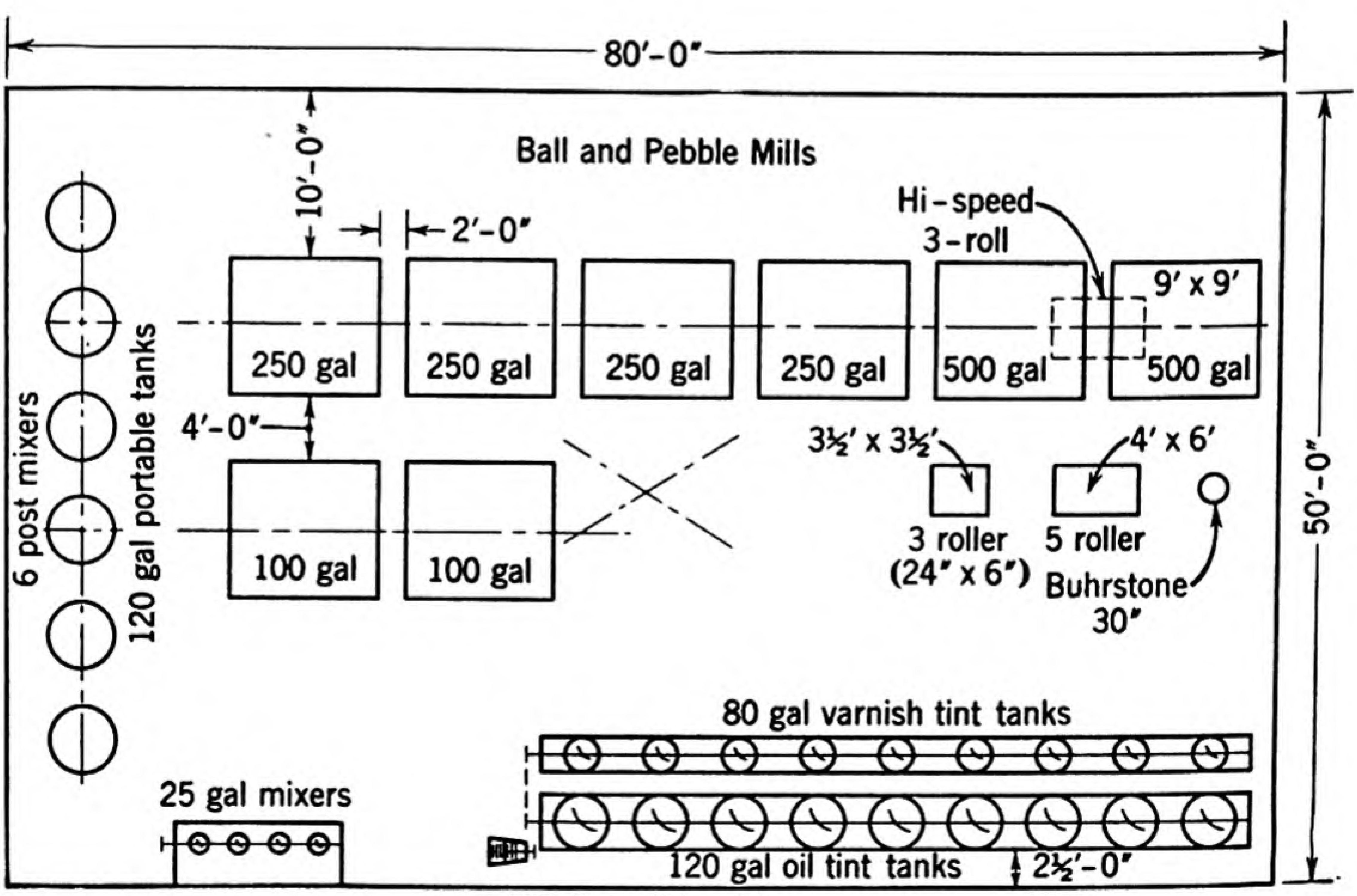
Fig. 13. Plan C. Vertical flow production.

composed of 40 per cent exterior paints, 45 per cent enamel products, and 15 per cent oil and liquid paste colors. Illustrations of the individual floor plans and suggested locations of equipment for each floor are shown in Figures 14, 15, and 16.



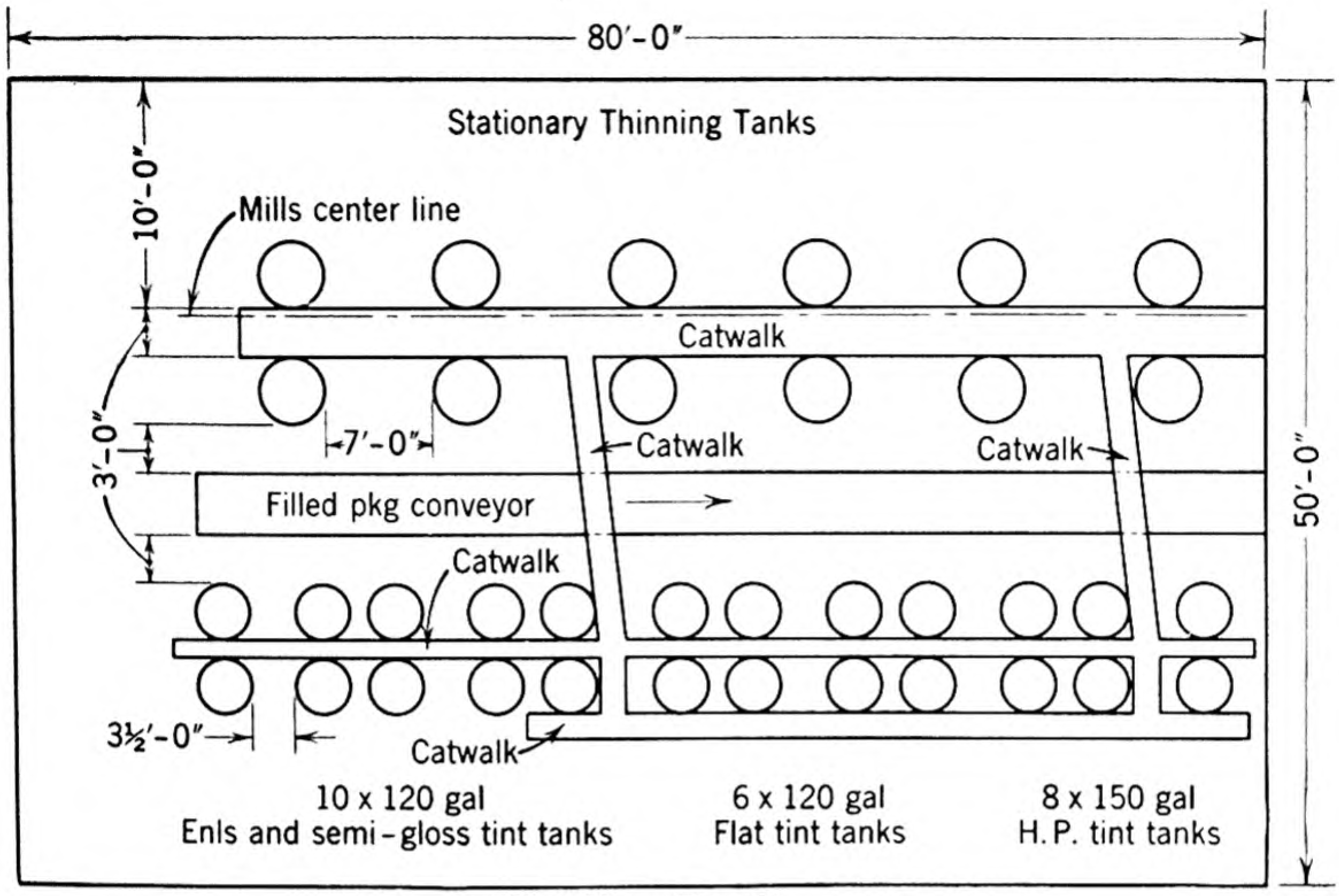
Top Floor (Plan *C*)

Fig. 14.



Mill Floor (Plan *C*)

Fig. 15.



Filling Floor (Plan *C*)

FIG. 16.

The dimensions of the building required to produce the above gallonage are 50 ft $\times$ 80 ft. The economical utilization of space on all three floors and general application of ball and pebble mills for grinding account for the relatively small dimensions required for the building proper.

Combination Flow

The principles of horizontal and vertical flow production are effectively combined in many plants, and Plan D (Figure 17) is an excellent example of such a scheme which is in actual operation.

The diagram shows the various operations in flow-sheet form beginning with the transfer of liquids by pumps and the handling of pigments by means of pallets directly to storage on the top floor. After grinding, thinning, and tinting, the finished goods are elevated in portable tanks to the top floor for filling by gravity. Labeling and packing then continue on a straight line until the finished products are dropped by conveyor to the storage and shipping departments.

The actual dimensions of Plan D provide 160,000 sq ft of manufacturing and storage space for an estimated capacity of 20,000 gal of paint and enamel per day. The three features of this plant which are unique involve a central weighing station for liquids, the suspension of ball and pebble mills from the ceiling of the mill room, and large 600-gal mobile

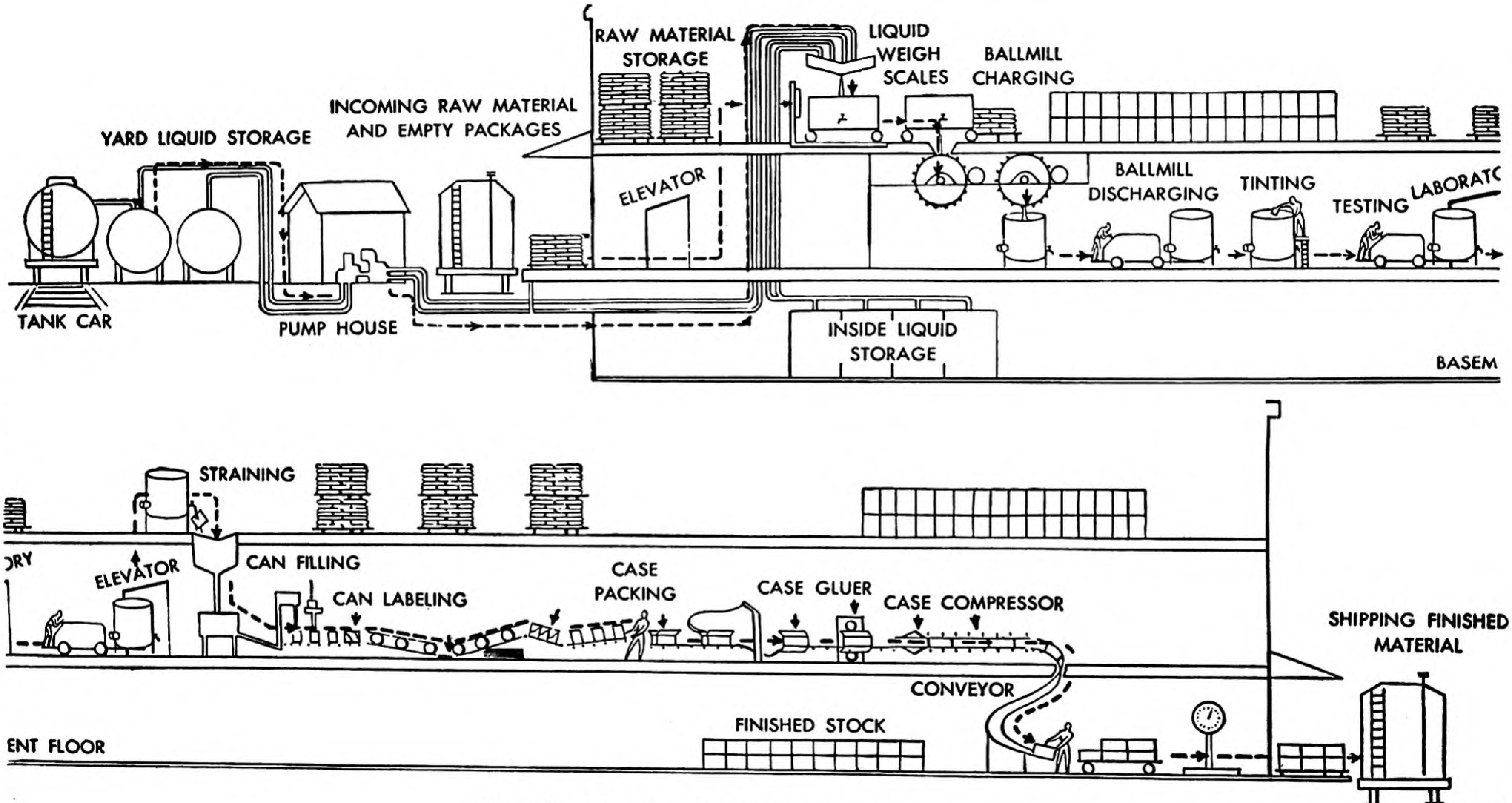


Fig. 17. Plan D. Combination flow production.

mixing tanks equipped with individual motor-driven agitators attached to the side of each unit.

Equipment

The manufacture of paints and pigmented coatings involves three basic operations—mixing, grinding, and thinning. Years of experience have been responsible for the development of machinery designed to satisfy effectively the mechanical requirements for each of these processes. The heavy weight and consistency of paint products require machines which are rugged to handle satisfactorily.

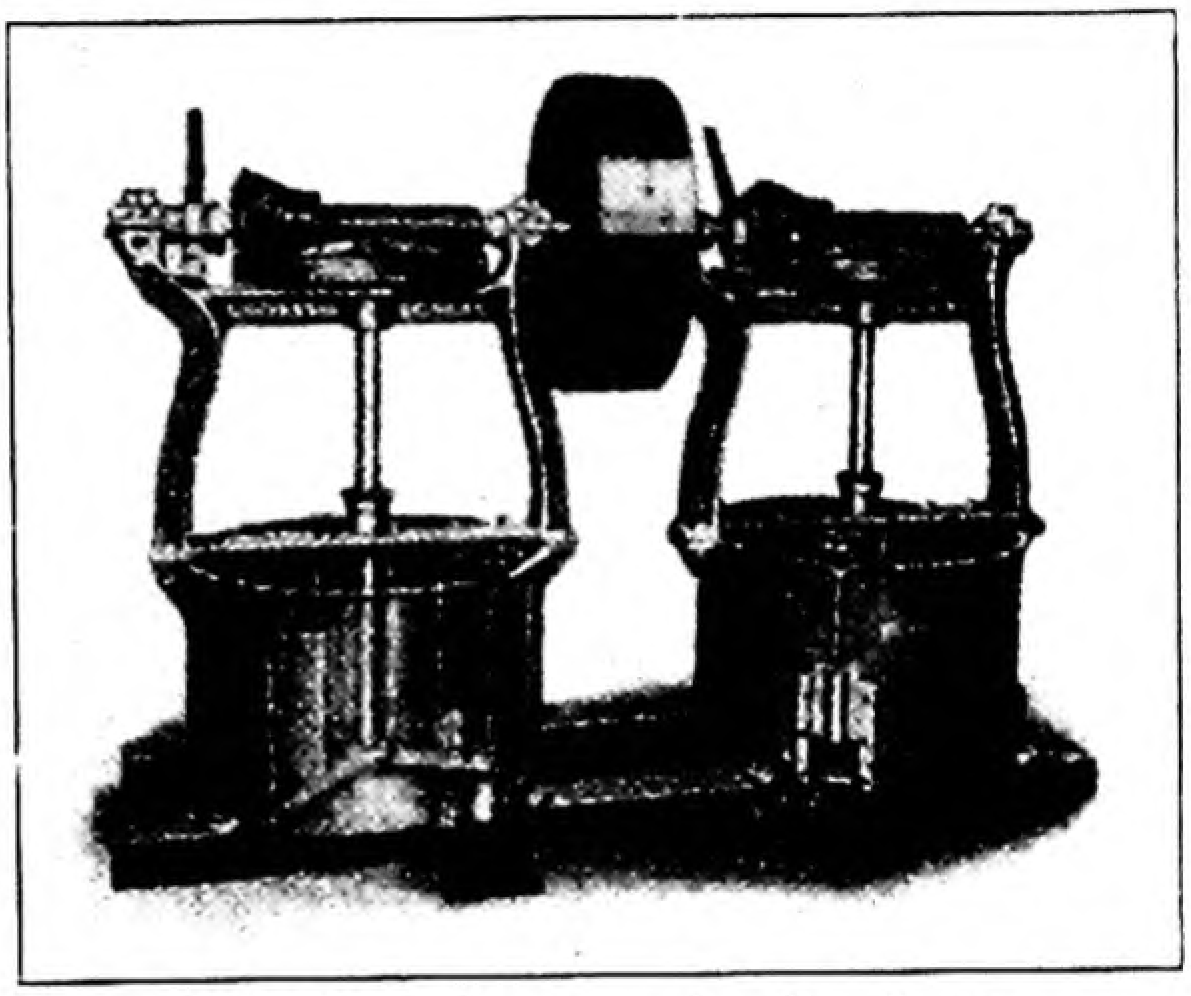


FIG. 18. Paste or lead mixers.

Mixers. Mixing equipment in general comprises several types; consideration will be given to the two most commonly used.

Paste Mixers. Heavy-duty paste mixers, which are stationary installations with a capacity of 80 to 125 gal, are the proper size for the average plant making a general line of paints. Paste mixers are heavily built and are designed for stirring the paste batches composed of dry pigments and liquids at very low speeds; they are available in single and twin units. Such mixers can be procured with or without clutches, either belt or direct driven, and are usually geared to run at 30 rpm. For ease of loading the units are available with low or high sides which vary in proportion to the diameter to meet individual preferences that have been expressed for each design.

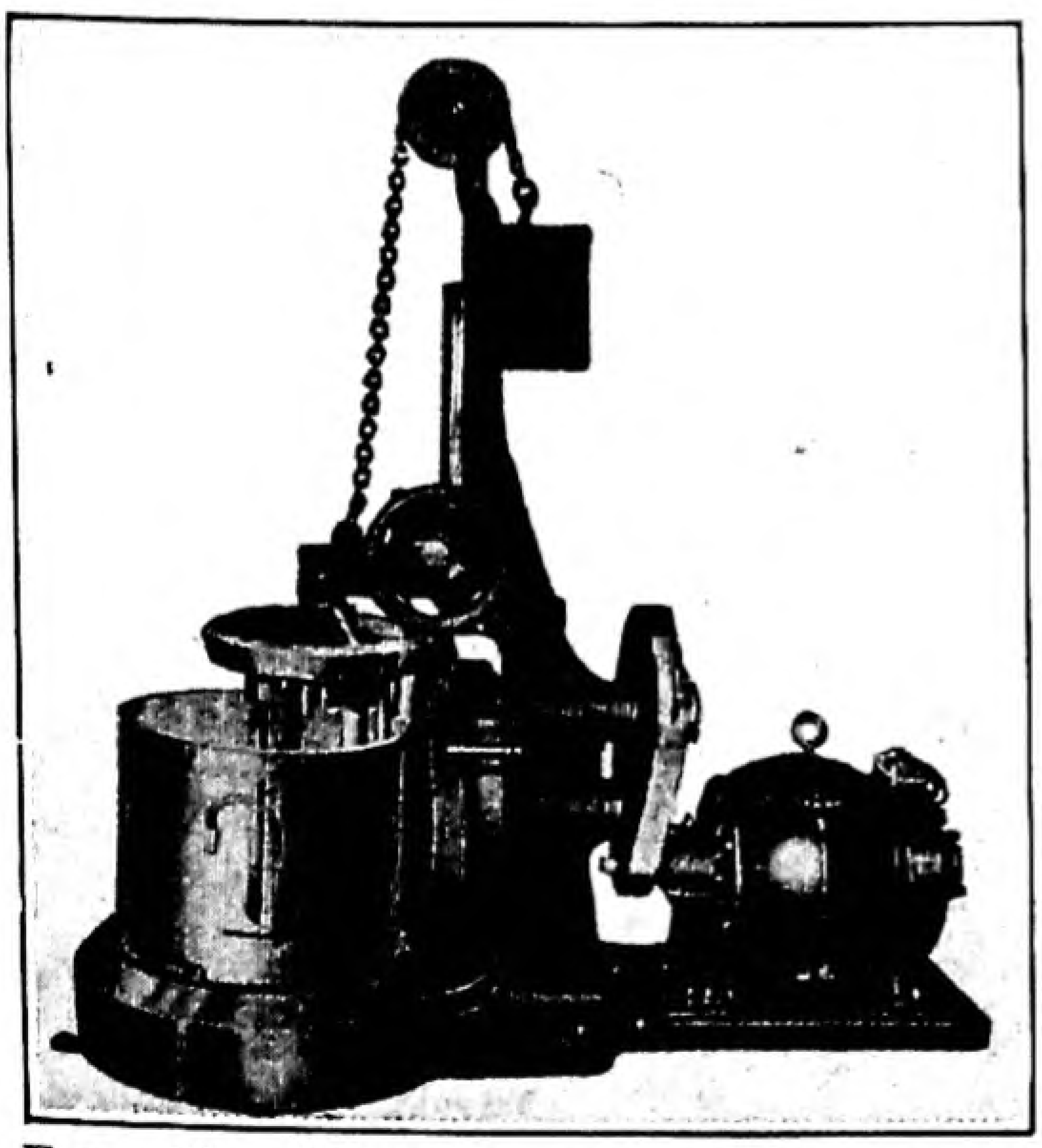


FIG. 19. Pony or change-can paste mixer.

Pony Mixers. Change-can, or the pony mixer, is representative of the second type which is standard equipment in all paint plants. Pony mixers vary in size from 16 to 125 gal. Several improved types have been developed and should be investigated carefully before a selection is made. Pony mixers are offered with single or double heads and with direct or belt drives.

One of the improved mixing devices is equipped with a double head that also includes a four-wheel dolly on which the mixing can is mounted.

The dolly and can when they are clamped to the mixer become an integral part of the complete mechanism. This arrangement performs well and permits the use of any number of cans with a single mixing unit, thus enabling quick color changes with a mininum amount of cleaning. They are available in 60- or 100-gal capacities with direct drive attached.

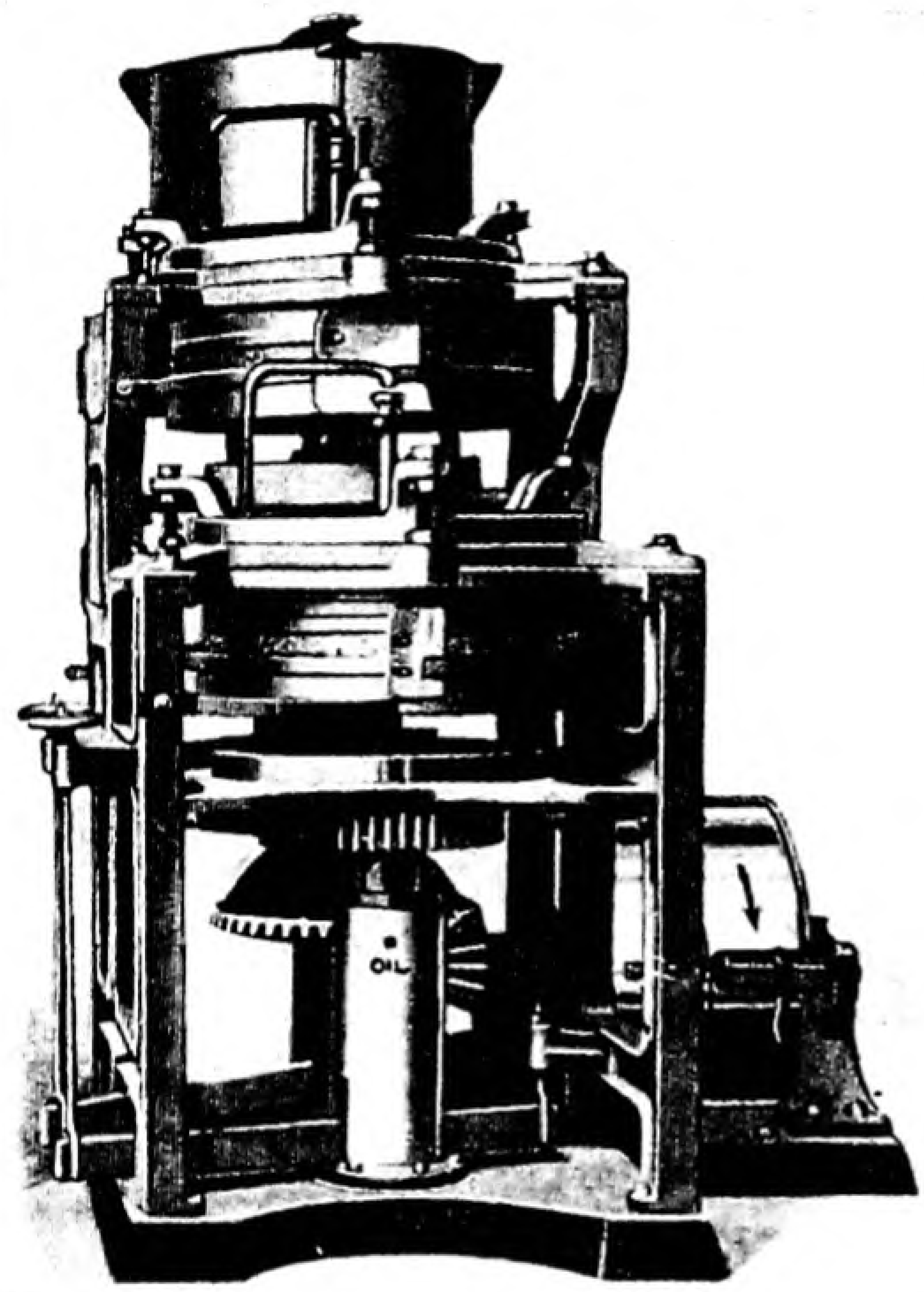


FIG. 20. Tandem stone mill.

Mills. For grinding or dispersing dry pigments in liquid media to an acceptable degree of fineness most manufacturers use several types of mills during this important step in the processing of paints and enamels. Only the customary grinding equipment will be discussed.

Stone Mills. The oldest machine which is still being used by the industry is the slow-speed stone mill. These mills are becoming obsolete because of high maintenance cost and low production output, but they occasionally serve as auxiliary equipment for grinding pastes containing abrasive pigments or for making small batches of special products.

Stone mills are constructed with one flat stone surface revolving horizontally against the face of another, both of which have been dressed or cut with furrows and grooves as shown in the accompanying photograph.

Single and tandem stone mills are available in sizes up to 36 in. in diameter.

High-Speed Stone Mills. High-speed stone mills have been developed and have found wide acceptance in the paint field. These machines are small in size and require an approximate floor space of only 4 sq ft per unit. The grinding surfaces consist of two carborundum stones of about 10-in. diameter with the top stone stationary and the bottom stone rotating in the neighborhood of 3600 rpm. The paint base flows by gravity from a conical-shaped hopper, mounted on top of the mill, into the eye of the mill and falls on a small impeller which is mounted on the end of the drive shaft for the bottom stone. The impeller mixes the paste before it passes between the stones. This equipment grinds

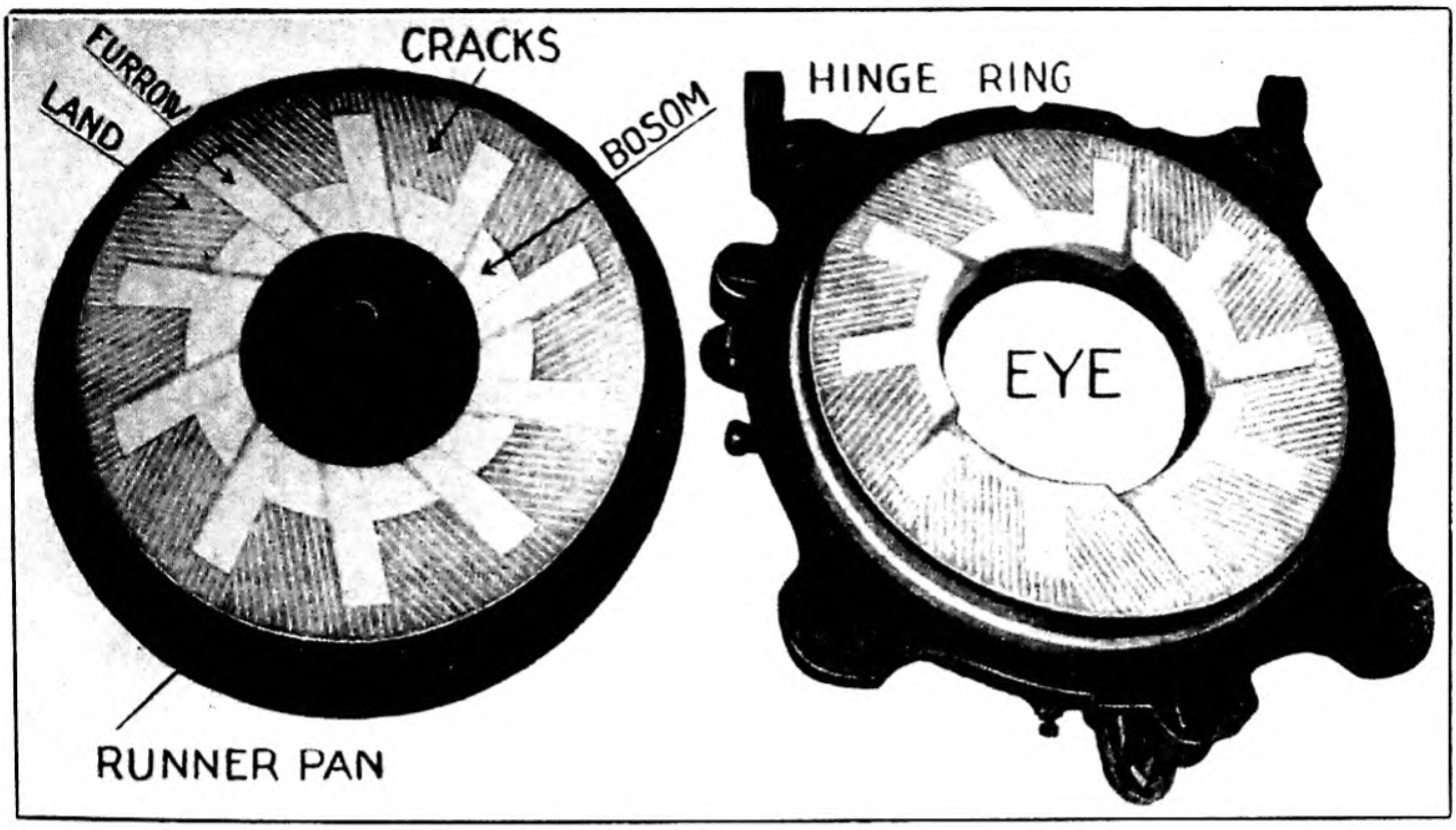


FIG. 21. Dressed stones.

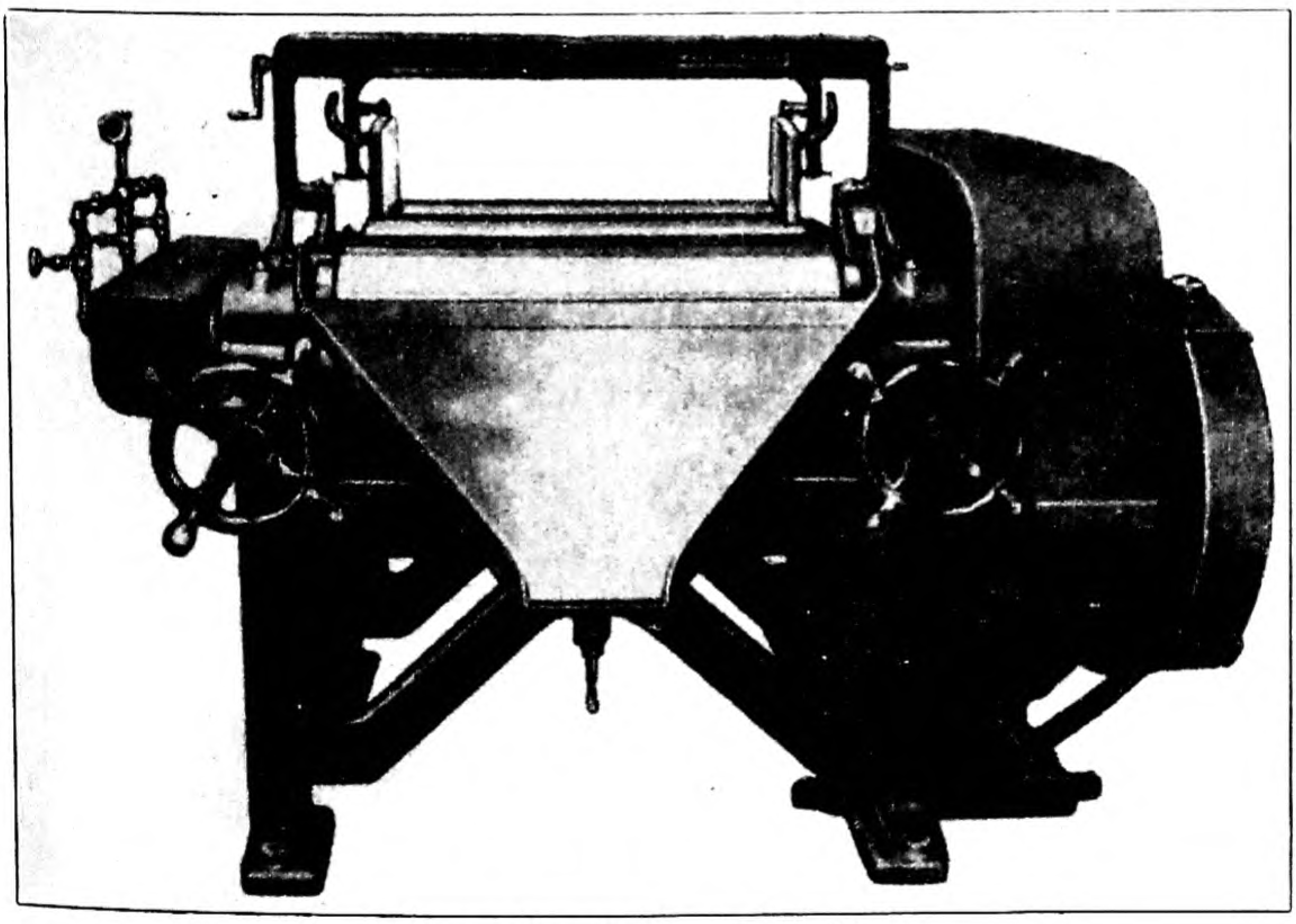


FIG. 22. Three roller mill.

pigmented products at a very fast rate and is most successful for flats, semigloss enamels, house paints, barn and roof paints, and many other coatings of this nature. The power is furnished by a 15-hp vertical motor which can be increased for special jobs and is direct driven and concealed in the shell of the machine. The mill is designed for easy cleaning at the end of each plant run.

Roller Mills. The roller mill is a versatile piece of equipment which

finds general application in the manufacture of pigmented materials. It is available in several sizes and employs from one to five rolls as the grinding mechanism. The three- and five-roll types are most common in the United States. These mills handle ordinary products, but abrasive pigments should be avoided to prevent excessive wear on the roller surfaces. Although some discretion is necessary for best results, roller mills are sturdily built and will last for many years if they are properly operated.

Dispersion of dry pigments into liquids is accomplished by the shearing action created by the counterrotation and varying speed of each roll. The speed ratio is approximately 1 to 3 between the pick-up and output roll, or 100 rpm for the first roll, 200 rpm for the second roll, and 300 rpm for the third roll. The paste being transferred from one roll to the next through adjustment and control of the pressure at point of contact is rubbed or torn apart by the speed differential, thereby allowing pigment particles to become wetted with the surrounding vehicle and finally removed from the last roll by a scraper knife attached to the apron.

These mills are usually direct driven by 15- to 25-hp motors, depending on the size of the mill. The equipment is extremely easy to clean and can produce up to 600 gal of first-quality finishes per day.

Pebble Mills. The pebble mill can be obtained in various diameters and lengths with almost any capacity desired. The ends or heads of the mill are usually cast iron, and the shell is steel; the inside of the cylinder is lined with either porcelain or stone (Silex or French Buhrstone). A shaft extends from the center of each head. These shafts ride in very heavy bearings supported on trunions or legs which can be mounted either on the floor or from the ceiling, the machine being suspended in a horizontal plane. A charging gate is located on one side of the cylinder with a grilled discharge valve on the opposite side. A large ring gear of the same diameter as the mill is either sweated or bolted to one end of the cylinder for rotating. The drive for this equipment may be by chain from the motor to jack shaft; by belt from the motor to jack shaft; or by gear reduction directly from the motor.

The grinding charge consists of porcelain balls for the porcelain-lined mills and flint pebbles for the stone-lined mills.

These mills can be used for grinding white gloss and semigloss enamels, flats, house paints, and other products. The sealed operating feature which excludes loss by evaporation is especially desirable with many materials. There is practically no discoloration of products because the components do not contact any metal surfaces. The mills require very little attention; they can be run during off-peak loads and hence are economical to operate. It is extremely important that the diameter of the

cylinder be large enough to allow proper cascading of pebbles or balls of the proper size when the mill is rotated.

Steel Ball Mills. Steel ball mills operate on the same principle as pebble mills but are unlined and jacketed for water cooling. The inner shell is made of chrome-manganese steel. The grinding charge is usually composed of chrome-manganese steel balls which are $\frac{5}{8}$ in. in diameter. This very tough and hard metal is employed to reduce wear

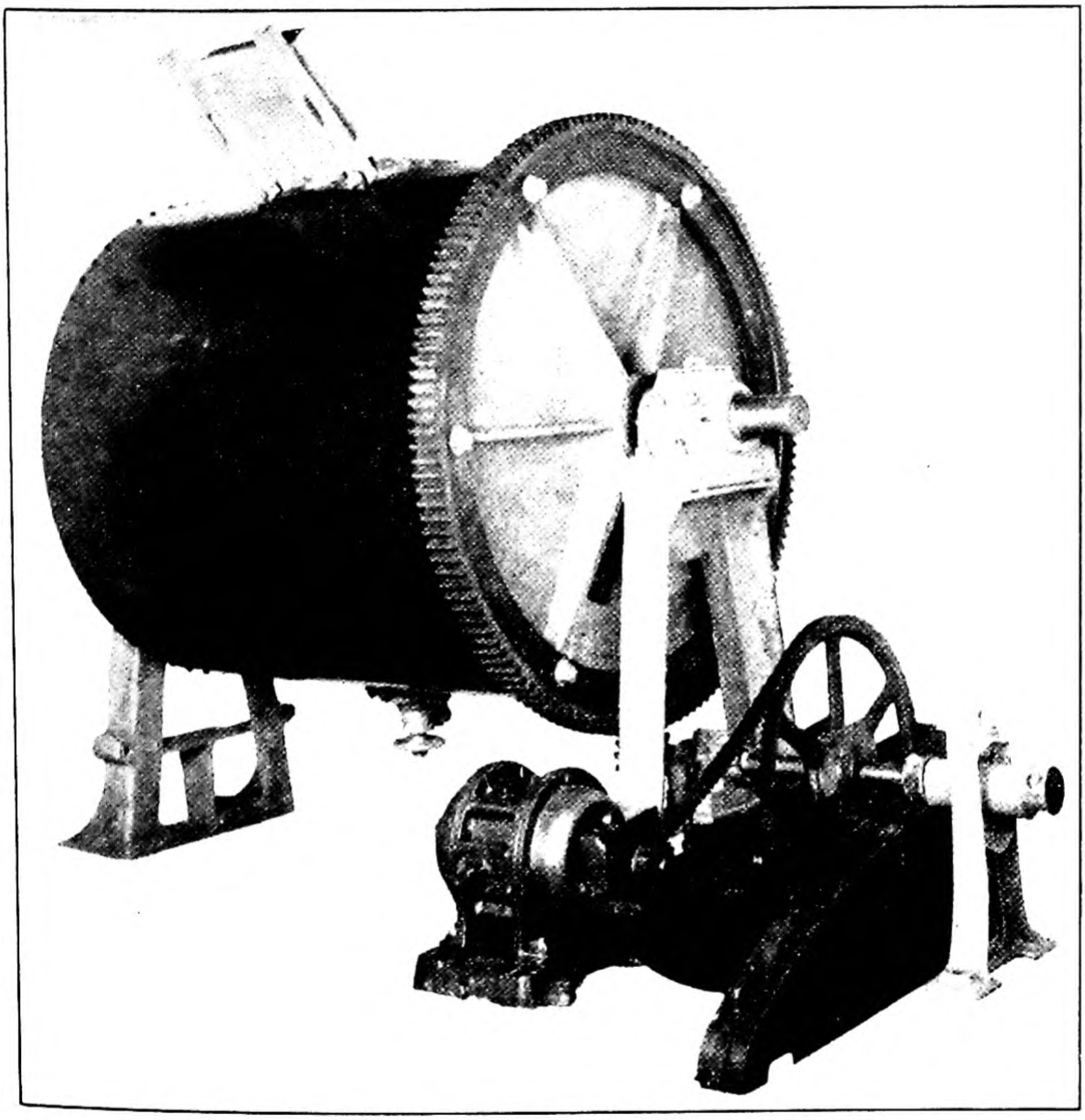


FIG. 23. Pebble mill.

and to minimize discoloration. Water cooling is generally necessary to remove the heat generated by the contact of metallic surfaces when the mill is in operation. These mills employ the same types of drives as those for rotating pebble mills. If the drive is gear head, the installation must be rugged enough to serve its purpose. Machinery manufacturers have a tendency to underpower these units. Generally speaking, fine grinds can be obtained with ball mills in much shorter time than with pebble mills, but they are not satisfactory for whites and very

light tints because of the slight discoloration caused by contamination with finely divided metal.

Tanks. Steel tanks which vary in shape and size are employed as receptacles for raw materials and goods in process.

Storage Tanks. Sufficient capacity for incoming shipments of oils, thinners, and other liquids must be provided not only to accommodate the requirements of the plant but also to be consistent with the purchasing policy of the company. Steel tanks which are installed above or below the ground in the yard will serve for bulk purchases of liquids that are thin enough to permit transfer through pipe lines. More viscous items can be carried in smaller stationary tanks within the plant or allowed to remain in drums as received. Manholes and covers, air-vents, discharge valves, and provisions for cleaning are standard accessories which must not be overlooked.

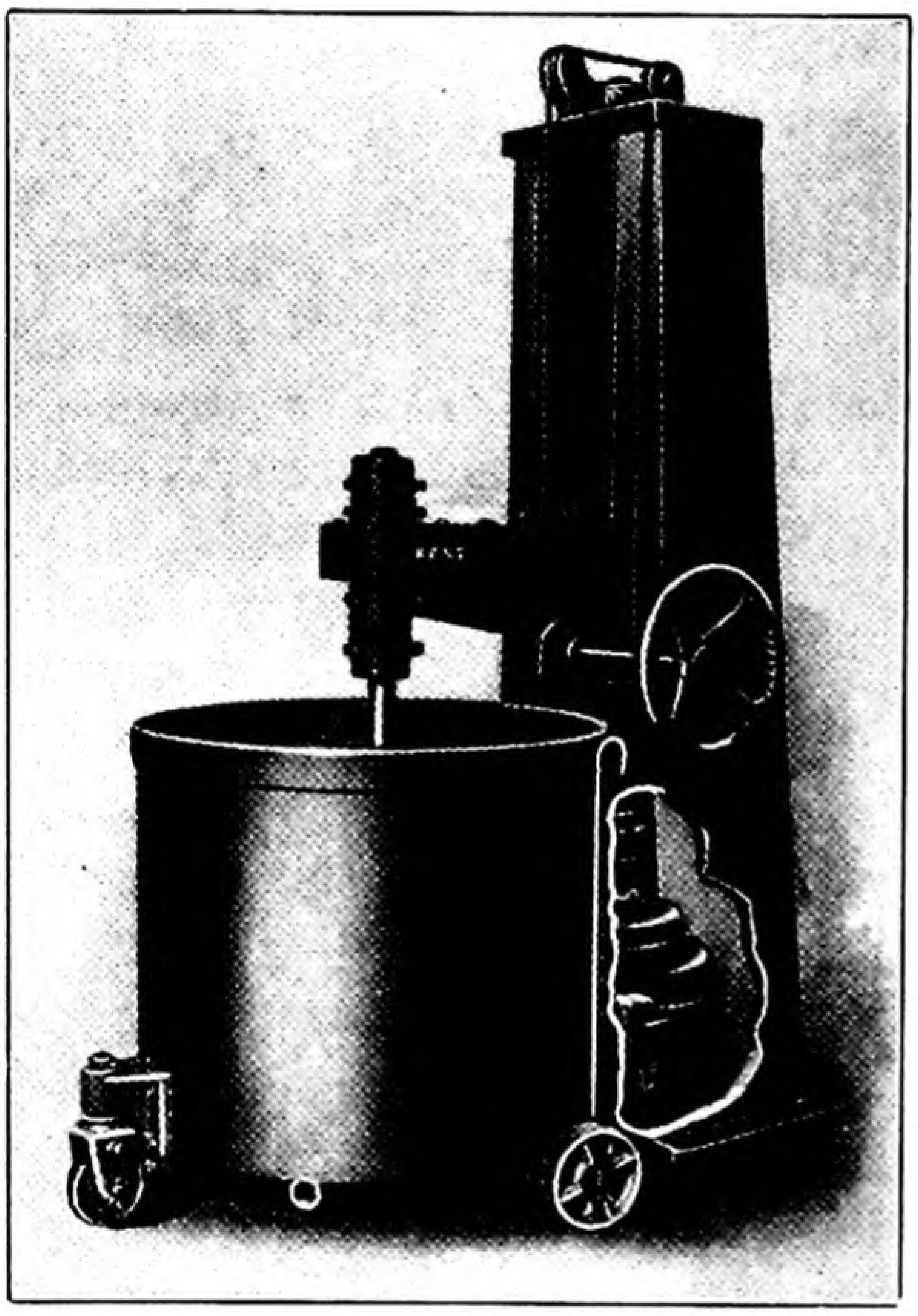


FIG. 24. Portable thinning tank.

Thinning Tanks. Most medium-sized plants use portable change-can tanks, rather than large stationary agitator tanks for thinning and tinting of batches. One obvious advantage is that the average plant batch of approximately 100 gal of finished material can be easily moved from one position to another. Many small stationary tanks would be necessary to handle the assorted lines of merchandise which most companies manufacture. The cost of cleaning stationary tanks is excessive and cleavage losses are high.

The portable-type tanks receive the intermediate bases directly from the mills and are then shifted to other locations for the thinning, tinting, and filling operations. Portable tanks should have a capacity of approximately 125 gal to allow ample room for agitation. It may be desirable to use a few stationary agitator tanks for tinting bases of house paint, flat, gloss, and semigloss products. Several such tanks of about 500 gal capacity each will provide auxiliary equipment to assist the production department during the periods of peak loads on grinding facilities and for the blending of two or more batches when required.

Agitators. When the paint base is ground into a portable change-can tank and while the driers and thinners are being added, it becomes necessary to agitate the material to obtain a thoroughly mixed and uniform product. If the batch is to be tinted, agitation is required during the entire operation to disperse the color properly. There are two types of agitators in general use for this part of the process.

Post Agitators. The stationary post agitator is a vertical machine with a large impeller mounted on the end of a shaft which can be raised and lowered by turning a manually controlled hand wheel connected

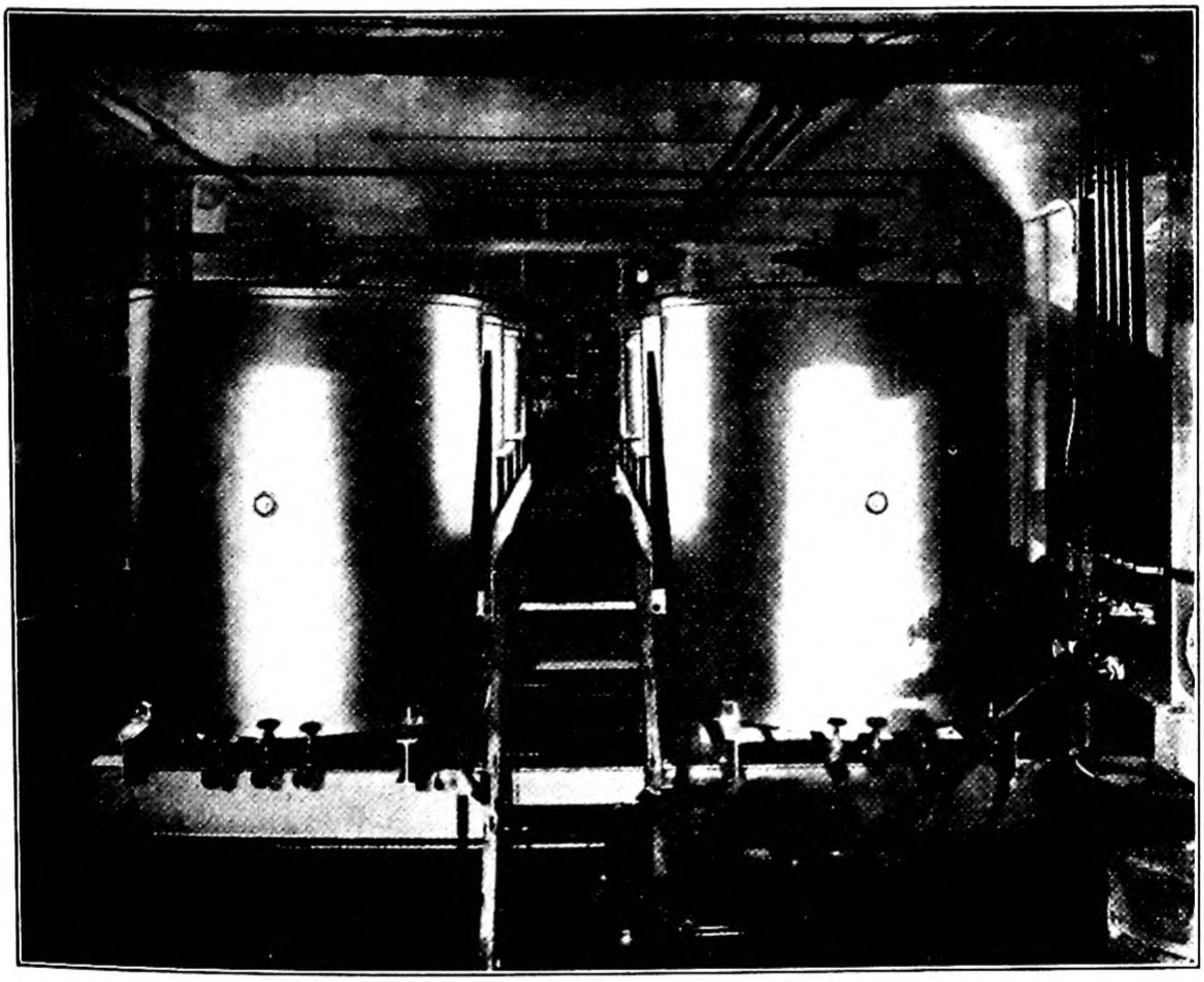


Fig. 25. Stationary tanks.

to a rack and pinion arrangement. This device operates at very slow speed but does a thorough job of mixing and will handle heavy materials.

The portable change-can tanks are moved to the stationary agitator, where thinning and tinting operations are completed. The agitator may be readily cleaned by immersing in a change-can tank containing mineral spirits.

High-Speed Portable Agitator. The second type of agitator is a high-speed mixing device consisting of an electric motor with a long shaft extension to which two small propellers are attached. These units are portable and are clamped to the sides of the change-can tanks. They

are convenient for simple mixing operations but should not be considered for the heavier tasks ordinarily required of post agitators.

Filling, Labeling, and Packing Requirements. In many plants the filling of containers is still a hand job. Machines work very well for large batches but entail an extensive cleaning up process. Hand filling is satisfactory for a simple production line where only one or two fillers are involved. An efficient procedure can be developed by pre-labeling the cans, either by machine or hand, filling the cans, then pushing the

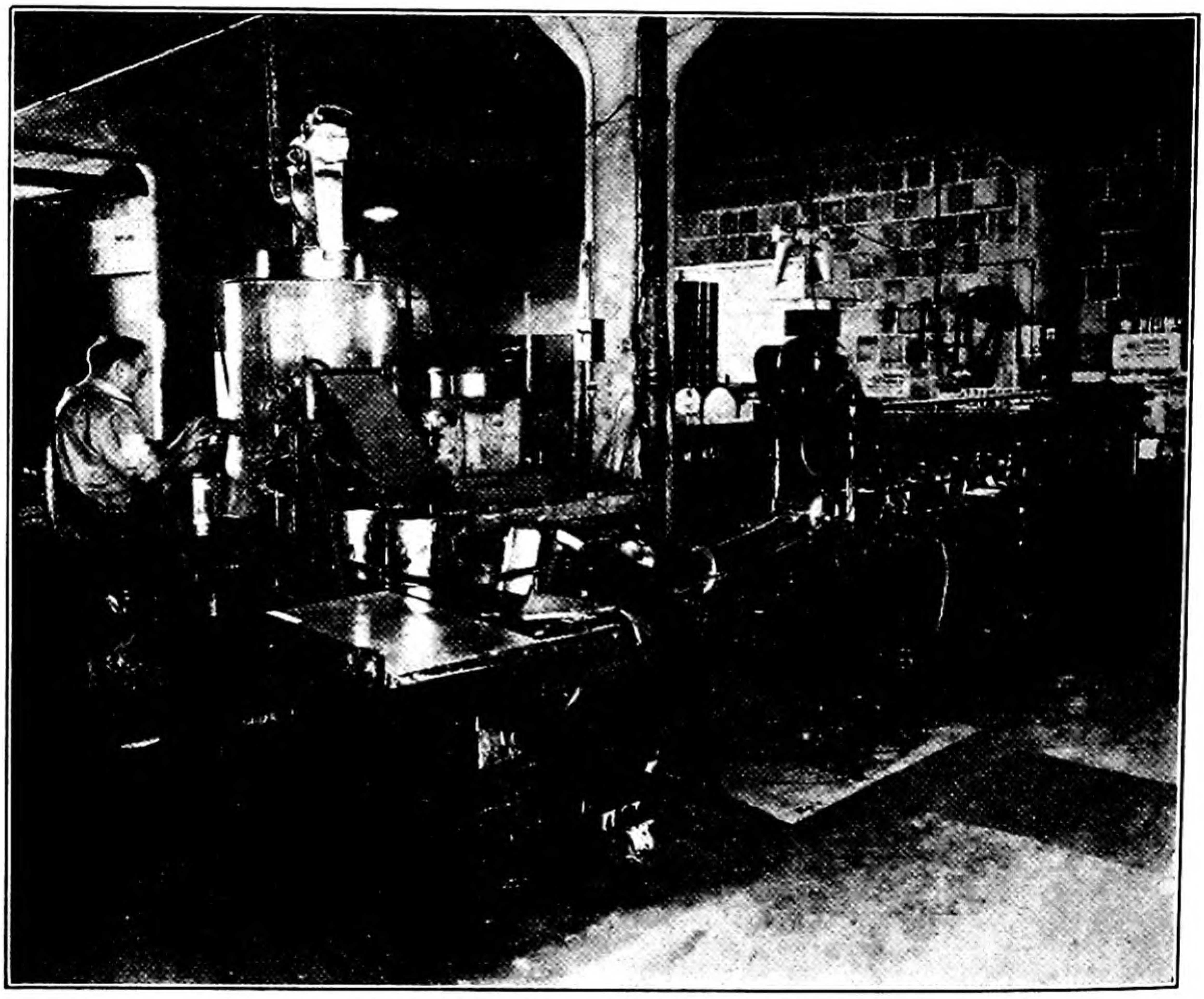


FIG. 26. Hand-filling assembly.

filled cans onto a conveyor which carries them under a capper. After leaving the capper the can should break an electric eye beam which actuates a rubber-stamping device that etches the code and batch number on the can lids. The labeled cans should then pass on to the packer who places them in cartons to complete the operation.

Some companies prefer to emboss the can lids; if this method of identification is adopted, the lids must be stamped separately and placed in stacks readily available to the filler.

When the plant volume is increased to the point at which more than

four packers are necessary, a carton-sealing machine is recommended. These machines will pack 600 cases per hour and can be changed from one size to another quickly.

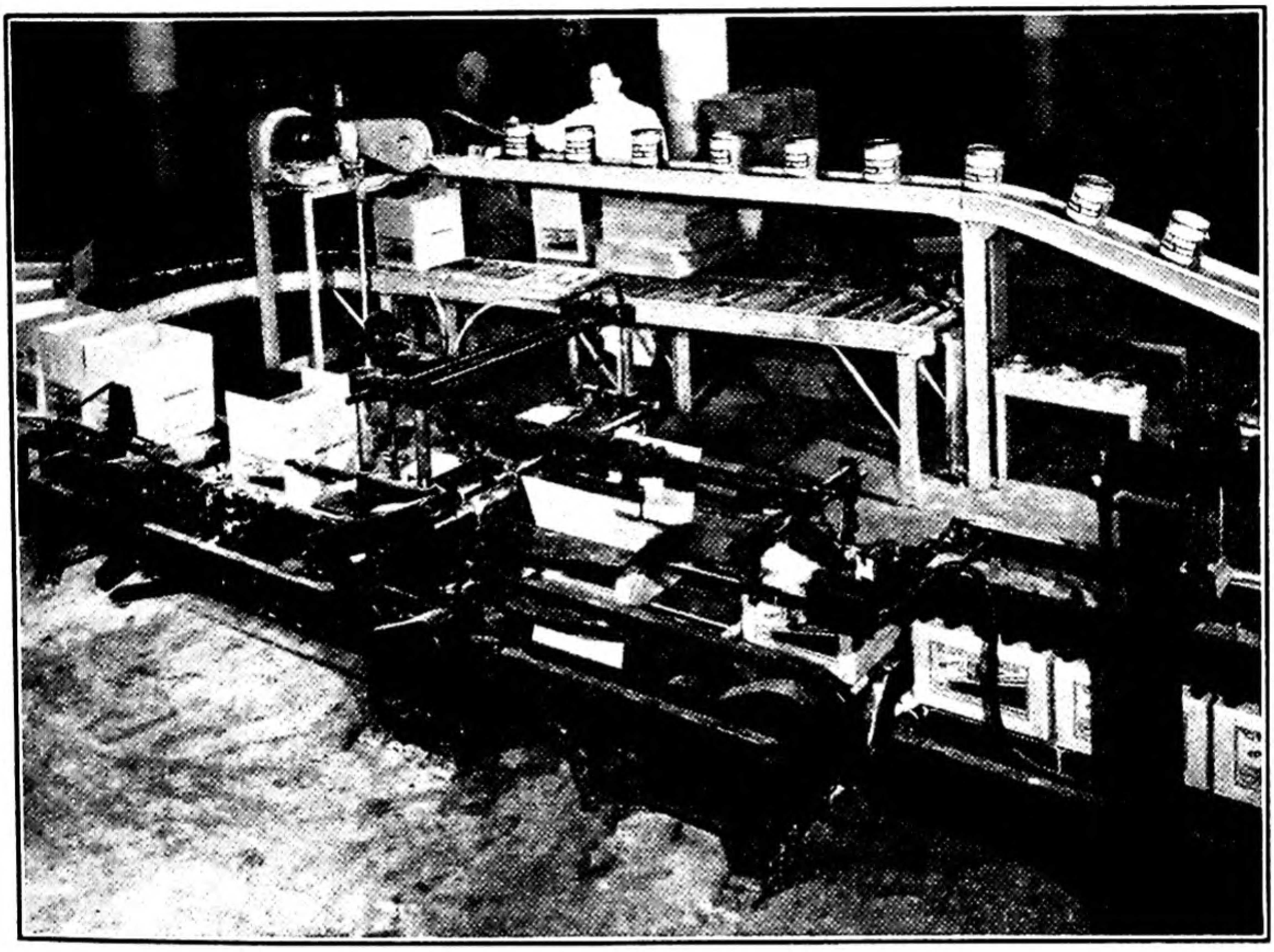


FIG. 27. Packing and sealing cartons.

Equipment Recommended for a Small Plant

Mixing.
2 twin stationary mixers (125 gallons each).
1 super pony mixer with five mixing cans and dolly (80-gal capacity).

Grinding.
1 high-speed stone mill.
1 12 in. x 30 in. three-roll mill.
1 pebble mill (200–250-gal capacity).

Thinning.
1 high-speed portable agitator.
1 stationary-type post agitator.
20 portable tanks (125-gallon capacity).

Batch Identification.
1 embossing or rubber-stamping machine.

Scales.
For mixing and thinning floors, the number and type of scales necessary will depend on methods used to handle pigments and liquids.

Filling.
If thinning and filling are to be done on the same floor, an electric hoist will be necessary. Strainers, filling attachments, and conveyors are essential accessories.

Labeling.

Hand labeling is satisfactory until the volume is sufficient to employ labeling machinery efficiently.

Packing.

When volume of packing in cartons becomes a problem, a carton sealer should be installed.

ACKNOWLEDGMENT

The editors are indebted to H. S. Mann and the Baltimore Paint and Varnish Production Club for their assistance on the subject of manufacturing equipment.

OFFICIAL DIGEST BIBLIOGRAPHY

Barkman, A., "Equipment and Methods for Manufacturing Paint," p. 630 (Sept., 1950).

Beach, A. T., "Pebble Mills," p. 243 (Nov., 1930).

Bonney, R. D., "Roller Mill Grinding (Review)," p. 345 (June, 1944).

Brown, H. M., "Ball Mills," p. 668 (Sept., 1948).

Cawood, R. L., "Modernize for Profit," p. 437 (Dec., 1935).

Cawood, R. L., "New Developments in the Grinding of Paint Products," p. 127 (Mar., 1940).

Drake, L. L., "Description and Illustration of the Master Mill," p. 505 (May, 1931).

Fischer, E. K., Rolle, C. J., and Ryan, L. W., "Pigment Dispersion with Ball and Pebble Mills," p. 1050 (Dec., 1948).

Foy, E. A., "Paint Mills," p. 19 (May, 1925).

Freeman, S. E., "A Modern Paint Plant," p. 995 (Dec., 1948).

Garlick, O. H., "Ball and Pebble Mills," p. 200 (May, 1936).

Grant, W. J., "Roller Mill Equipment," p. 599 (Sept., 1949).

Hanley, J. R., "Proportioning Equipment as Related to Weight Measurement," p. 1027 (Dec., 1948).

Henzey, W. H., "Pebble Mill Developments," p. 350 (Oct., 1935).

Horack, W. R., "Paint Mills," p. 250 (Sept., 1937).

Kleinfeldt, H. F., "Pebble Mills," p. 509 (May, 1931).

Kloppenstein, G. J., "Proportioning Equipment as Related to Volume Measurement," p. 1025 (Dec., 1948).

MacKay, A., "Aloxite Grinding Wheels," p. 13 (May, 1929).

Montreal Club, "Layout of a Modern Paint and Varnish Plant," p. 395 (Nov., 1945).

Moore, J. C., "Grinding Mills," p. 308 (May, 1944).

Moore, J. C., "Report of Processing and Equipment Group of M and M Committee," p. 613 (Dec., 1944).

Moore, J. C., "Paint Plant Manufacturing Equipment," p. 212 (May, 1946).

Morehouse, G. H., "The Principle of Grinding Paint on a Carborundum Stone Mill," p. 199 (Apr., 1949).

New England Club, "A Comparative Study of Hand and Machine Filling," p. 108 (Jan., 1948).

Phelps, N. J., "Grinding Tests Made with the Marco Kom-binator," p. 681 (Dec., 1946).

Serner, H. E., "Principles of Fluid Mixing and the Application of Mixing Devices," p. 1046 (Dec., 1948).

Shuger, H., "New Equipment," p. 106 (Jan., 1948).

Simpson, R. C., "Synthetic Mill Stones," p. 706 (Dec., 1931).

Simpson, R. C., "Further Investigations of Synthetic Mill Stones," p. 160 (Apr., 1935).

Stevens, G. R., "Filling and Packaging," p. 1067 (Dec., 1948).

Vasel, G. A., "Paint Grinding Machinery," p. 211 (June, 1937).

Whiteway, P. J., "Labeling Machines and Filling Machines," p. 2 (July, 1920).

ADDITIONAL FEDERATION OF PAINT AND VARNISH PRODUCTION CLUB PAPERS

Baltimore Club, "Buhrstone Mill Dressing," *NPVLA Sci. Sec. Cir.* 445, p. 432 (Nov., 1933).

Chicago Club, "A Modern Paint Plant," *NPVLA Sci. Sec. Cir.* 341, p. 904 (Nov., 1928).

Chicago Club, "A Modern Lacquer Plant," *NPVLA Sci. Sec. Cir.* 341, p. 916 (Nov., 1928).

Probeck, E. J., "The Use of Present Equipment in Lacquer Manufacture," *NPVLA Sci. Sec. Cir.* 291, p. 293 (Oct., 1926).

CHAPTER 3

VARNISH PLANT

The facilities for varnish manufacturing should involve as few buildings as possible wtih maximum convenience for the movement of materials in process. Regardless of the plan adopted, certain compromises are inevitable, depending on the particular needs of the manufacturer.

The layout should be carefully designed with suitable provision for direct flow through the plant. One-way traffic is desirable, beginning with the raw materials to the cooking fires, coolers, and thinning operation and thence to the kettle-cleaning section, after which the process can be repeated.

Liquid raw materials, when used in quantities, should be stored in large tanks, preferably outdoors in concrete-lined pits and connected to the department using them by pumps and pipe lines.

Solid raw materials should be located on an upper floor near the stacks, so that cooking equipment can be charged by means of chutes. Smaller quantites can be conveniently kept on the ground floor.

The conventional cooking house is usually a single-story building with fires on one side and arrangements for cooling on the other. The thinning room should be isolated from the cooking room and separated from it by at least 30 ft.

Storage tanks for finished products can be housed in a tall building with the minimum number of windows, doors, or openings in the side walls. All openings should be protected with steel fireproof doors.

Provisions for fire escapes and also the convenience of service lines for power, steam, water, and drainage must be considered.

Cast-iron plates, approximately 2 ft square, are very satisfactory for those sections of the varnish plant floors which are subject to excessive wear from heavy traffic.

Spacing of manufacturing units at proper intervals is essential. Ample space provides comfort for employees, encourages cleanliness and orderly operating procedure, and contributes appreciably to reducing the hazards which are associated with the manufacture of varnishes and similar products.

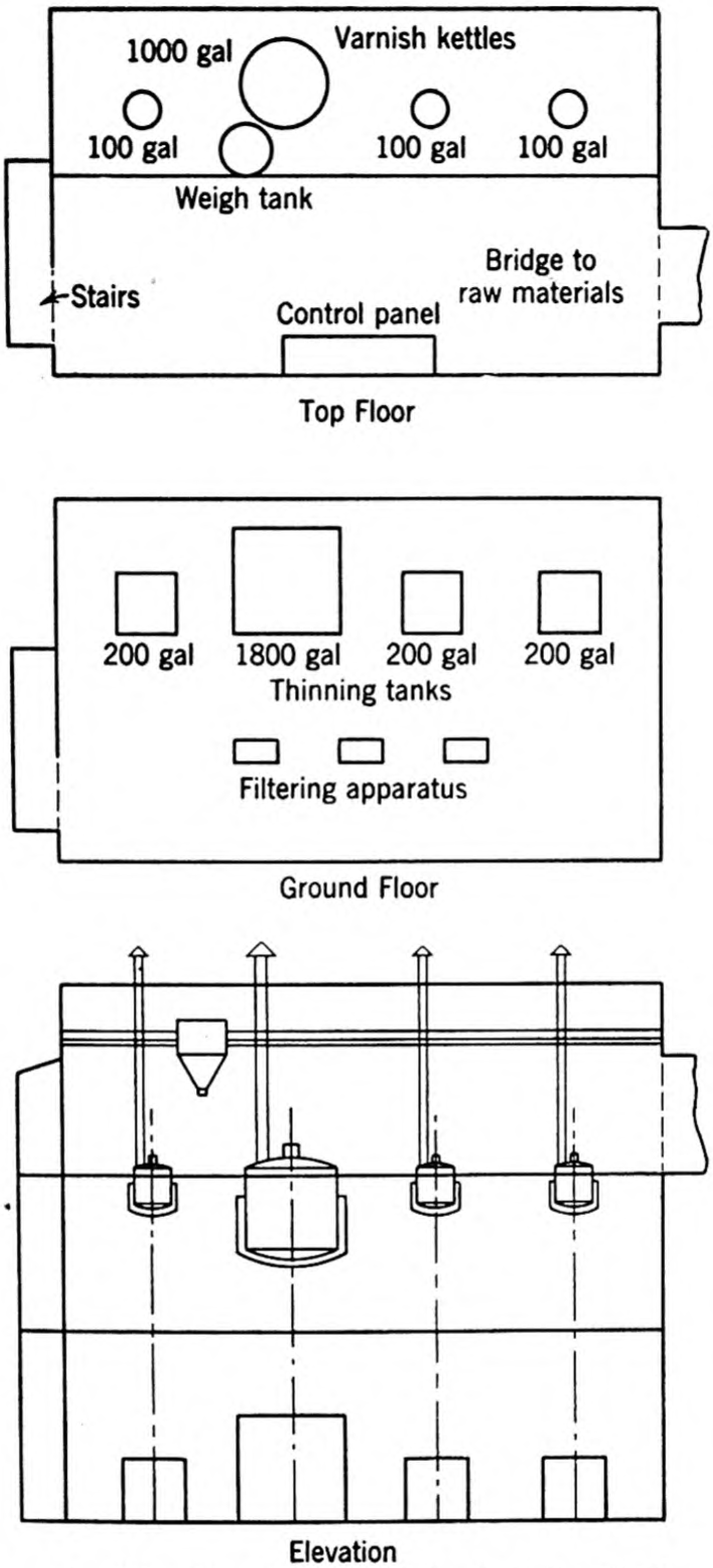


Fig. 28. Plan E. Varnish plant (vertical).

Vertical Design

In conjunction with the manufacture of paint products as recommended by the Montreal Paint and Varnish Production Club in the previous chapter, a varnish plant has been designed which has a maximum capacity of 3000 gal per day. The layout is shown in Plan E which provides for a three-story building with cooking operations on the

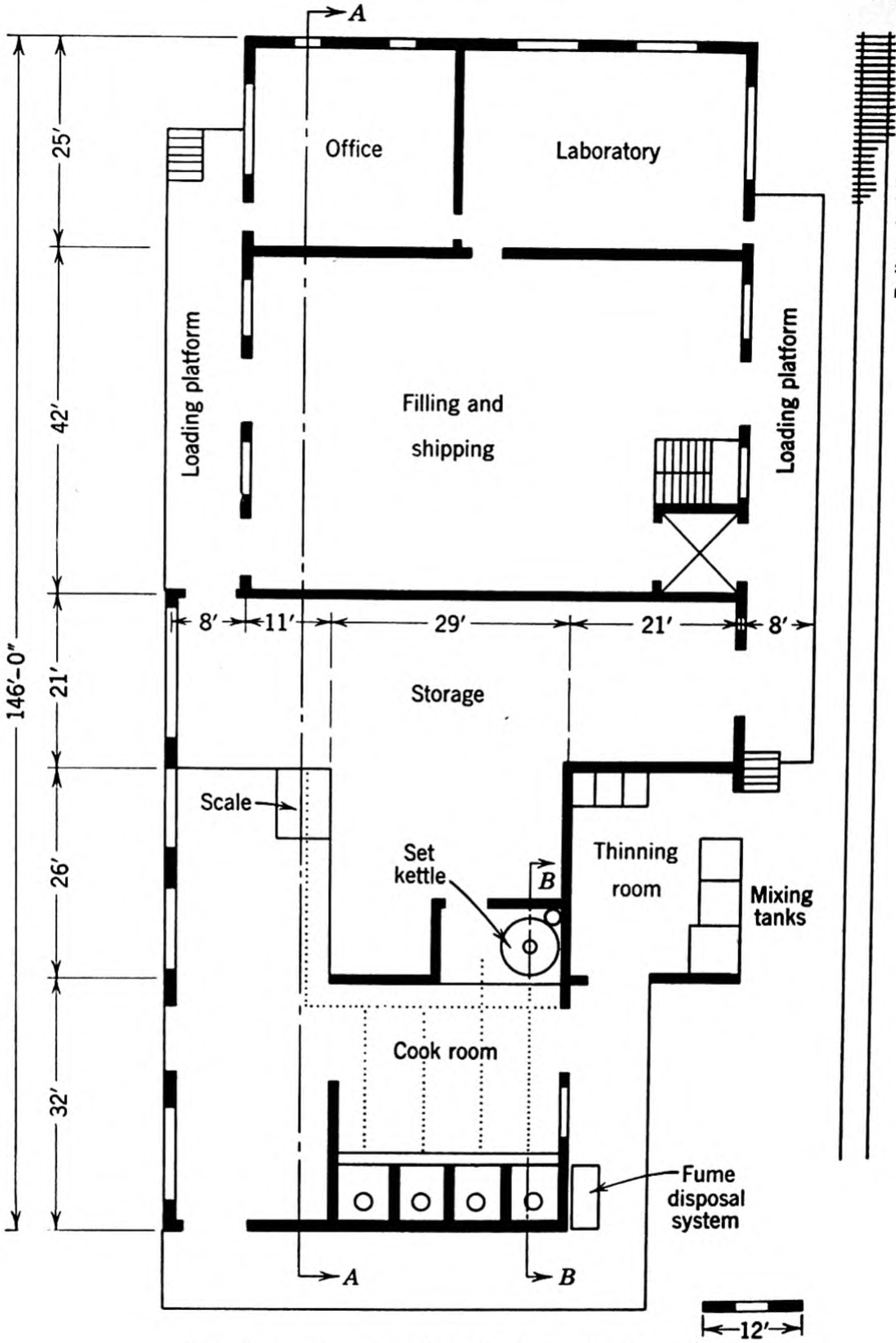


FIG. 29. Plan F. Varnish plant (horizontal).

top floor and thinning and storage on the ground floor. The kettles are stationary and are embedded in the top floor for ease of loading. Contents after processing are discharged by gravity through openings in the bottom of the kettles.

Horizontal Design

Modern facilities for the manufacture of varnish have been recommended also by the Philadelphia Paint and Varnish Production Club, and an operating layout for a daily capacity of 3000 gal is shown in Plan F. Arrangements for outside storage of oils and thinners in tanks and of resins in drums are provided, and finished stocks are pumped to tanks on the second floor for blending and filling by gravity.

Since the manufacture of certain intermediates and finished goods permits the use of set kettles for large-volume production, an alternate scheme is demonstrated in Plan G for such an installation of varnish and resin kettles.

Mobile and Stationary Systems

Mobile Equipment. Mobile equipment is used extensively in varnish making. As a simplified method for intermittent production, the process consists of heating resins and oils in portable kettles over open fires in separated stalls or stacks, then thinning and pumping to tanks before either centrifuging or filtering for final storage.

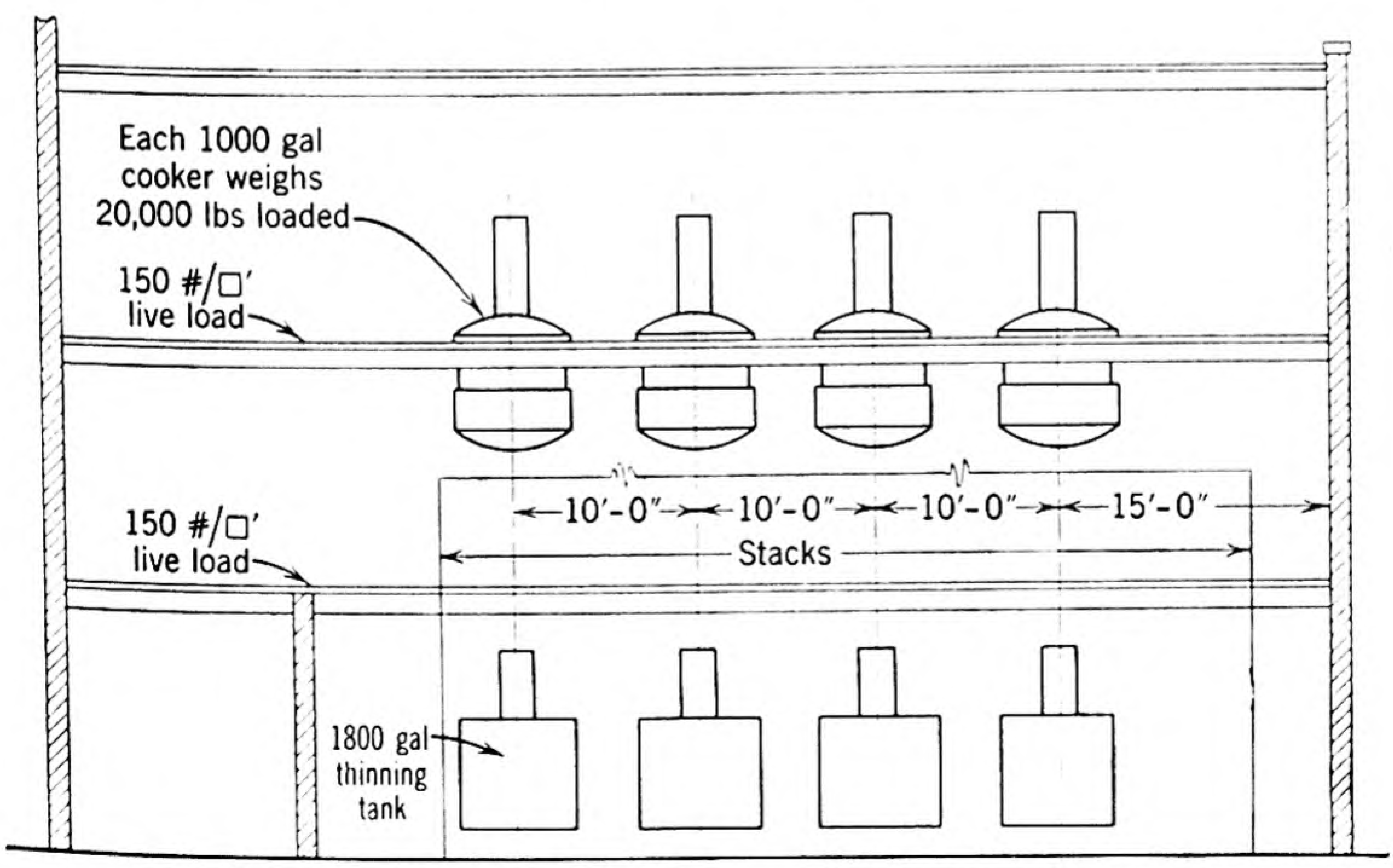


FIG. 30. Plan G. Stationary varnish and resin kettles.

Portable Kettles and Trucks. The most common size for portable kettles is 38″ in diameter and 38″ in height (capacity 185 gal). Other sizes which are popular are 40″ by 40″, 42″ by 42″, and 48″ by 48″ (217, 250, and 376 gal, respectively). Larger-size portable kettles are made, but they require specially built trucks.

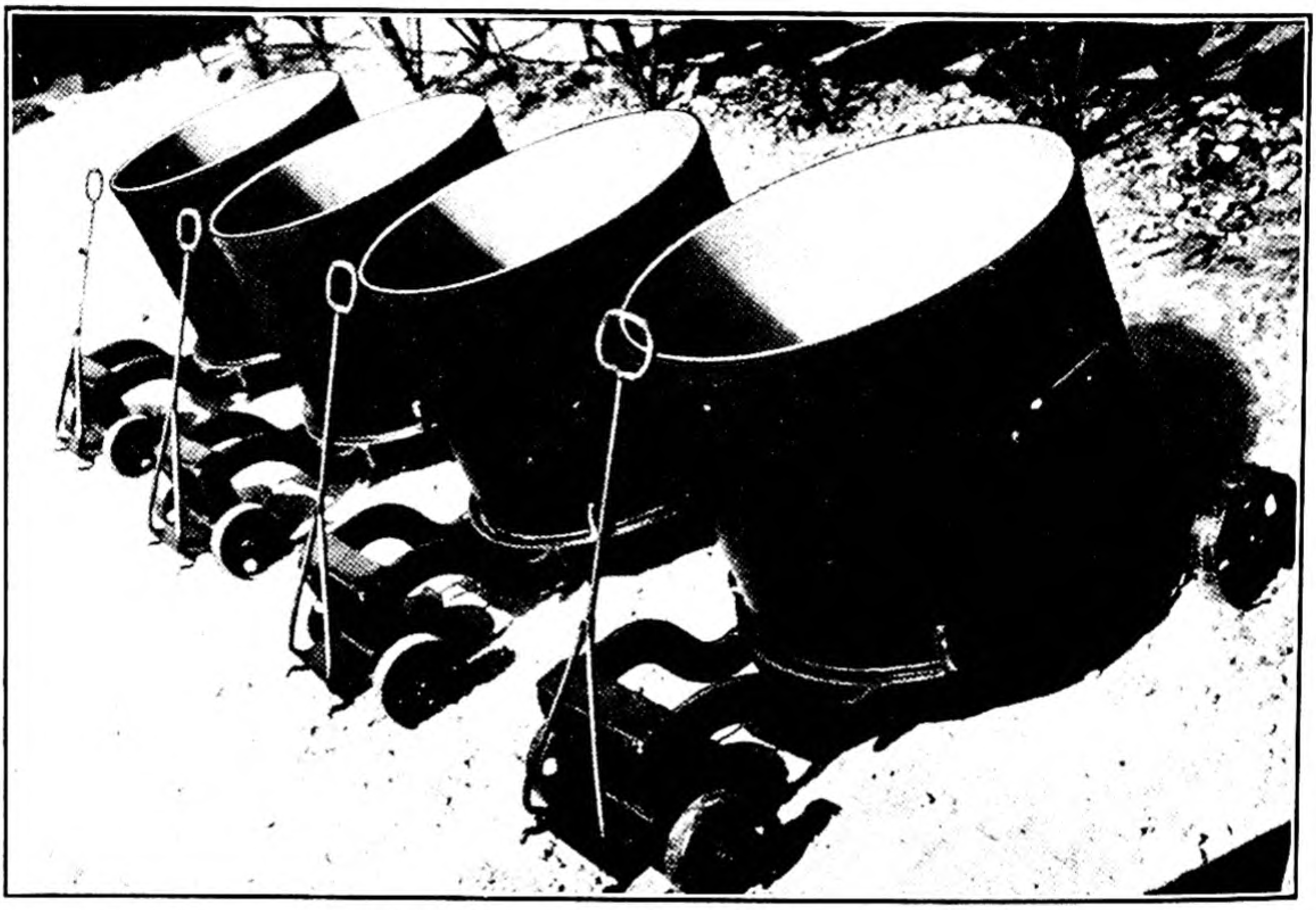


FIG. 31. Portable varnish kettles.

Trucks should be as light and rugged as possible. Three-wheel trucks are probably the most maneuverable. However, they cannot be used in all plants because the air duct for the fire pit may interfere with the front pivot wheel. This situation will then necessitate four-wheel trucks with an arched carriage which requires the extra wheel to balance the load. The center of gravity of the trucks should be as low as possible to prevent tipping. Steel parts for trucks give the best performance under operating conditions; the direct heat of the fire, however, should not come in contact with the axles.

Metals for Kettle Construction. The properties, advantages, and disadvantages of the various metals for kettles are given in Table 1.

Kettle Repairs and Lubricants. Only expert welders and mechanics should repair any kettle. Usually it is better to send kettles back to the manufacturers for estimates and repairs of all kinds. Steel kettles, however, may be repaired locally by a good electric welder because they do not require preheating or annealing.

As lubricants for bearings on varnish kettles and trucks are exposed to relatively high temperatures, a rather heavy lubricating oil seems to give best results. It is advisable to consult with an oil company for recommendations as to the proper type and grade.

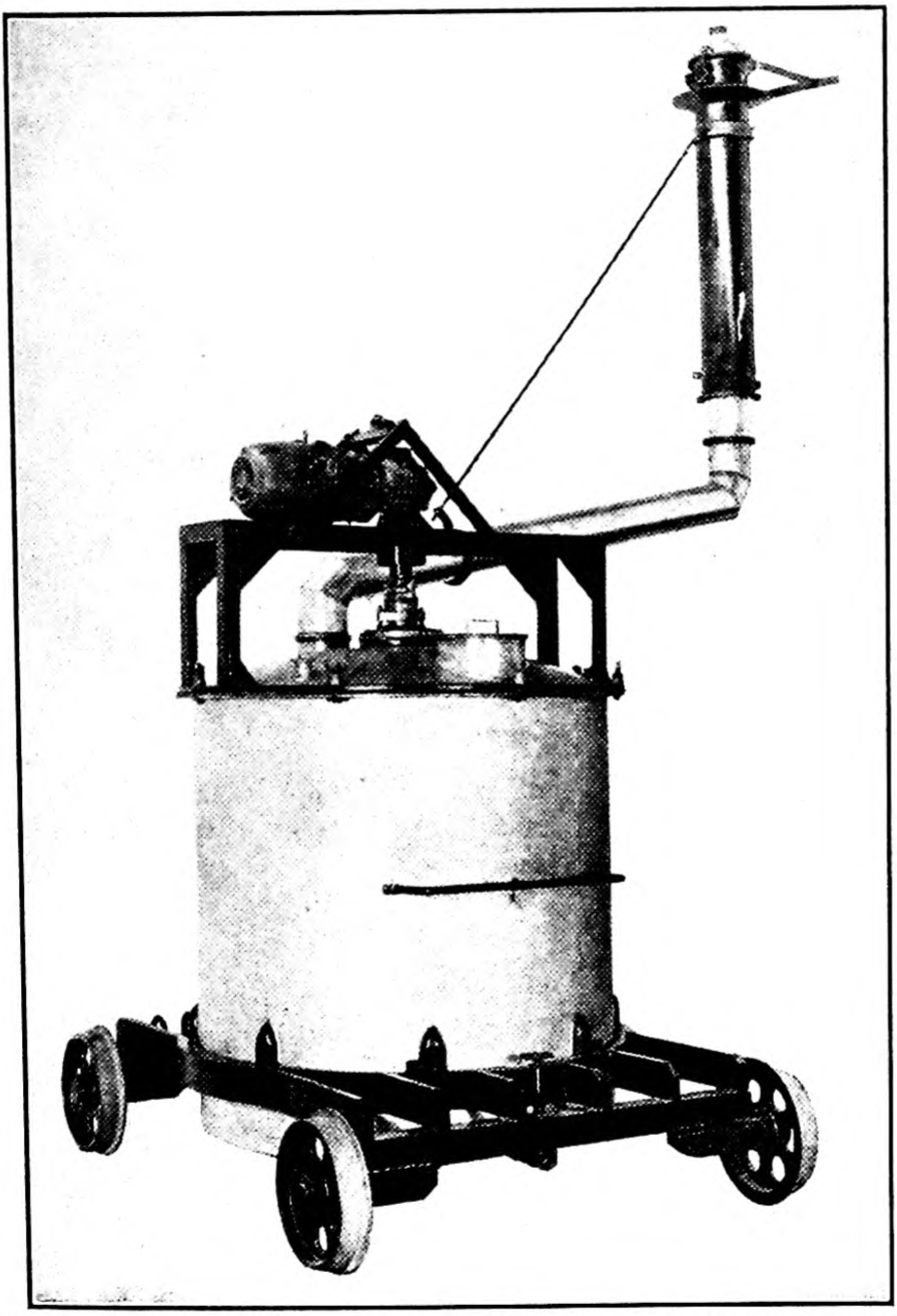


FIG. 32. Large portable resin kettle with agitator and reflux condenser.

Stationary Equipment. Large-scale resin and varnish production may be handled mechanically with very little manual labor, from the time the raw materials arrive until the finished product emerges. This method of processing requires extensive and complex stationary equipment for its success.

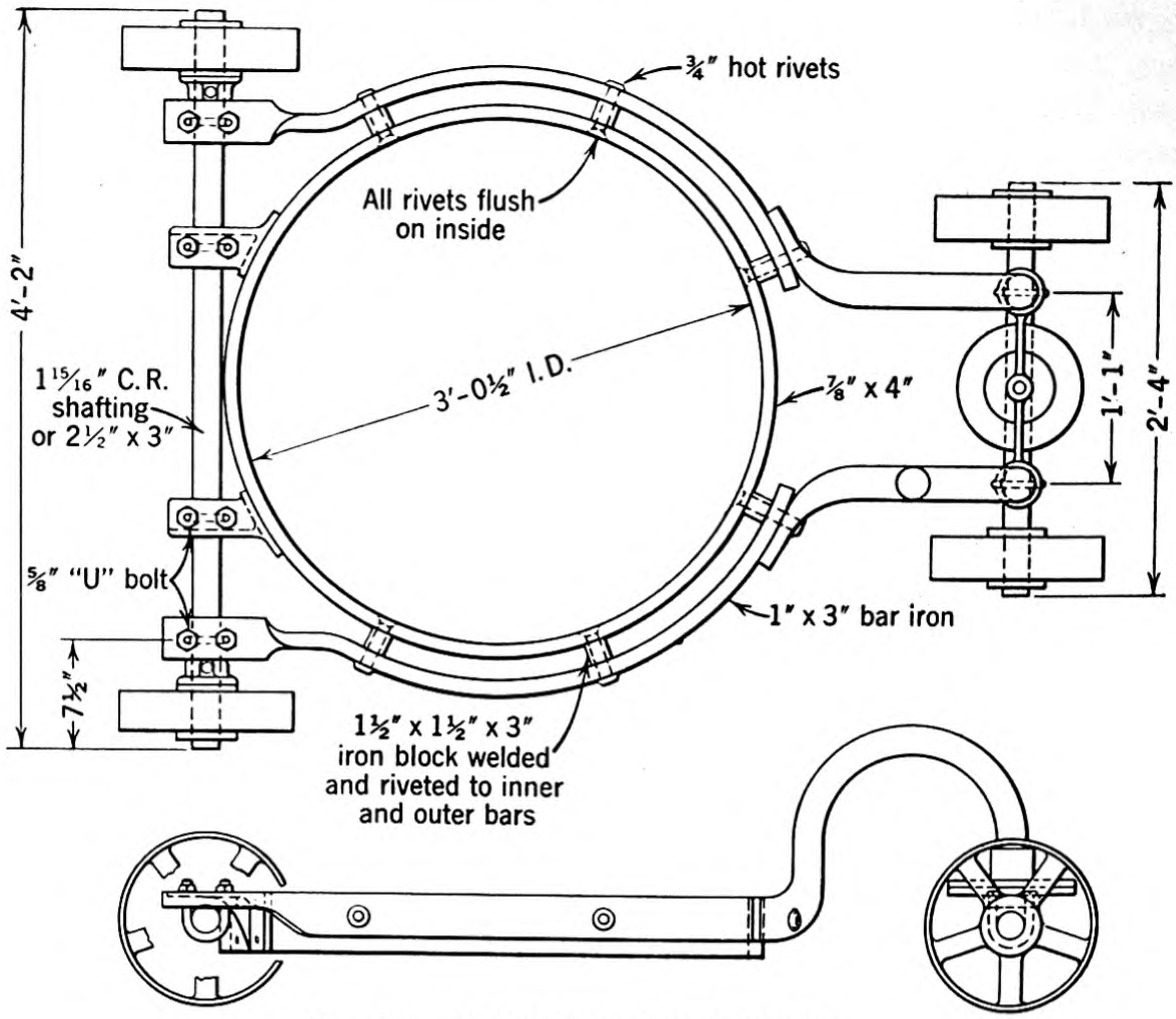


FIG. 33. Detail of truck for 36" kettle.

TABLE 1
COMPARISON OF METALS

Metal	Relative Cost	Tensile strength Lb/Sq In.	Color of Varnish	Heat Transfer Coeff.	Advantages	Disadvantages
Steel	1	40,000	Poor	310	Low cost Stands abuse Good for blacks	Poor for varnish
Copper	2½	30,000	Fair	2630	Medium cost Excellent heat transfer	Unsatisfactory for certain products
Monel	4–4¼	65,000	Good	180	Good color Long wear	High initial cost
Nickel	5	60,000	Good	410	Same as Monel	Same as Monel
Aluminum	2¾–3	18,000	Excellent	1420	Excellent color Catalyzes some reactions	Low tensile strength Cannot clean with caustic
Stainless steel	3½–4	75,000	Excellent	113	Excellent color Resists corrosion Long wear Resists caustic and most acids	High initial cost Low heat transfer

The primary units in the system are kettles in which batches ranging from 500 to 2000 gallons can be made. These tightly closed reactors, usually fabricated from stainless steel are equipped with mechanical agi-

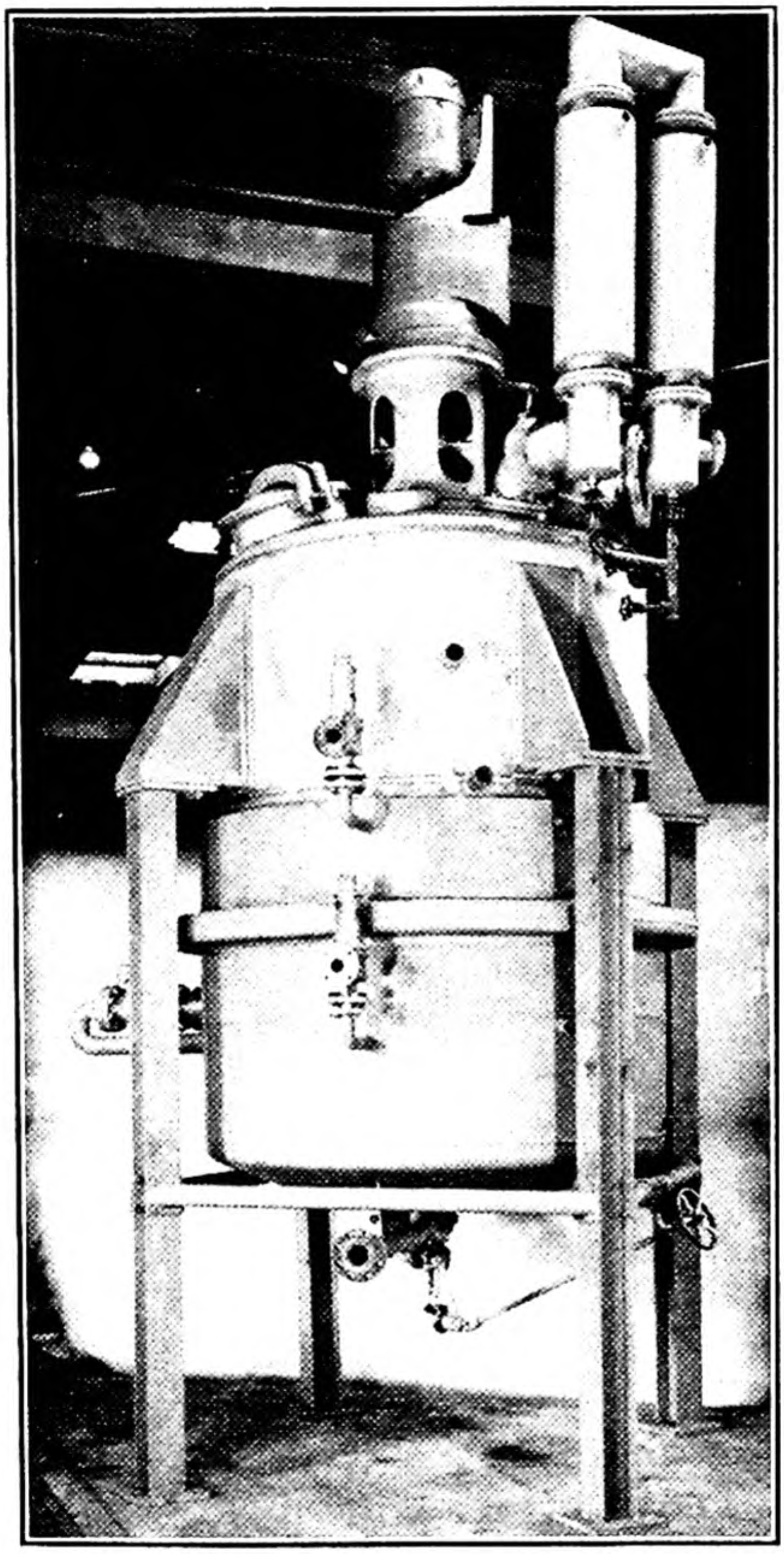


FIG. 34. Stationary reaction kettle.

tators and fitted with condensers for distillation or refluxing; they can be operated under a blanket of inert gas in vacuum or under pressure. Heating and cooling can be regulated as desired. Temperatures and time cycles are controlled and recorded automatically. The weighing and transfer of raw materials into the kettles are also accomplished mechanically. The most important auxiliaries for stationary kettles are described briefly in the following paragraphs.

Weigh Tank. The weigh tank is a small unagitated tank which measures raw materials accurately; it should be located above the kettle

so that the contents may be dumped by gravity. It should be mounted preferably on recording scales and connected to the kettle by flexible outlets.

Agitators. Agitation is accomplished by an explosionproof motor-driven agitator, with a stainless steel shaft running through a lantern-type stuffing box which provides packing as well as the connections for

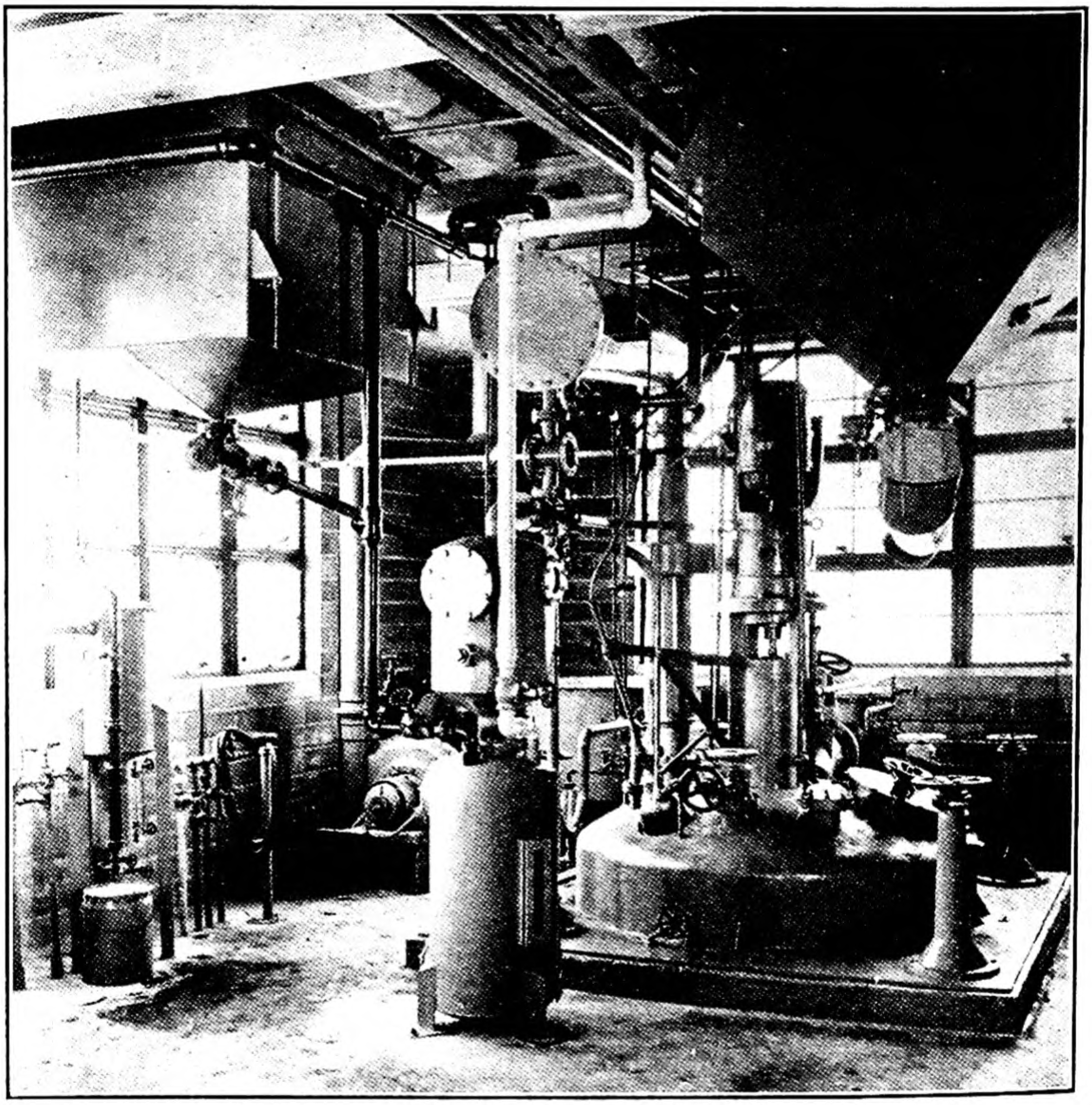


FIG. 35. Dowtherm-heated resin kettle installed.

inert gas. The method of mixing may be propeller, paddle, or turbine revolving from 100 to 125 rpm for best results in larger kettles. Continuous agitation is essential during the cooking process and until the batch is ready for thinning.

Reflux Condensers. Reflux condensers on the kettles serve to condense vapors which evaporate before final heating is attained. The condensate may be separated and removed or returned constantly to the

batch. A simple condenser of the single-tube type is usually adequate. Complex formulations, however, often require a multi-tubular condenser or group of condensers with liquid seals, catch-all tanks, and other accessories.

Carbon Dioxide Gas. The presence of CO_2 gas in the reaction kettle is practically mandatory. A blanket of inert atmosphere in the kettle and above the batch at all times reduces oxidization and discoloration

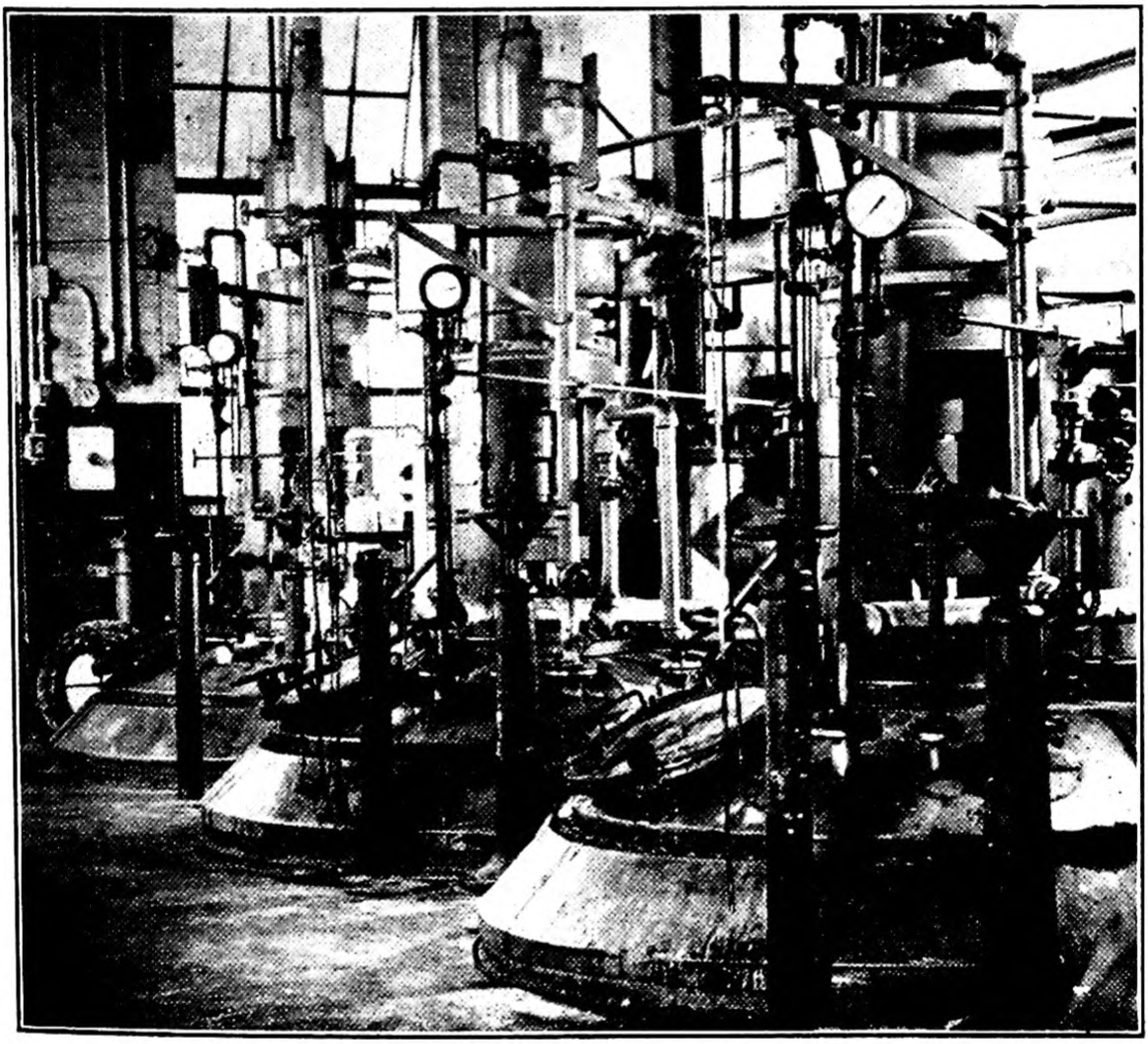


FIG. 36. Multiple resin kettle installation.

and prevents flashing if the batch becomes overheated. Good kettle design provides for release of the gas on the bottom so that it may bubble through the reacting materials.

Thinning Tanks. Stainless steel is considered the best metal for thinning tanks. They must be equipped with agitators and the same types which are used for the cooking kettles are satisfactory. The tanks should also be equipped with reflux condensers to reduce evaporation losses and to prevent the formation of internal pressure.

Many thinning tanks are installed on recording scales which allow

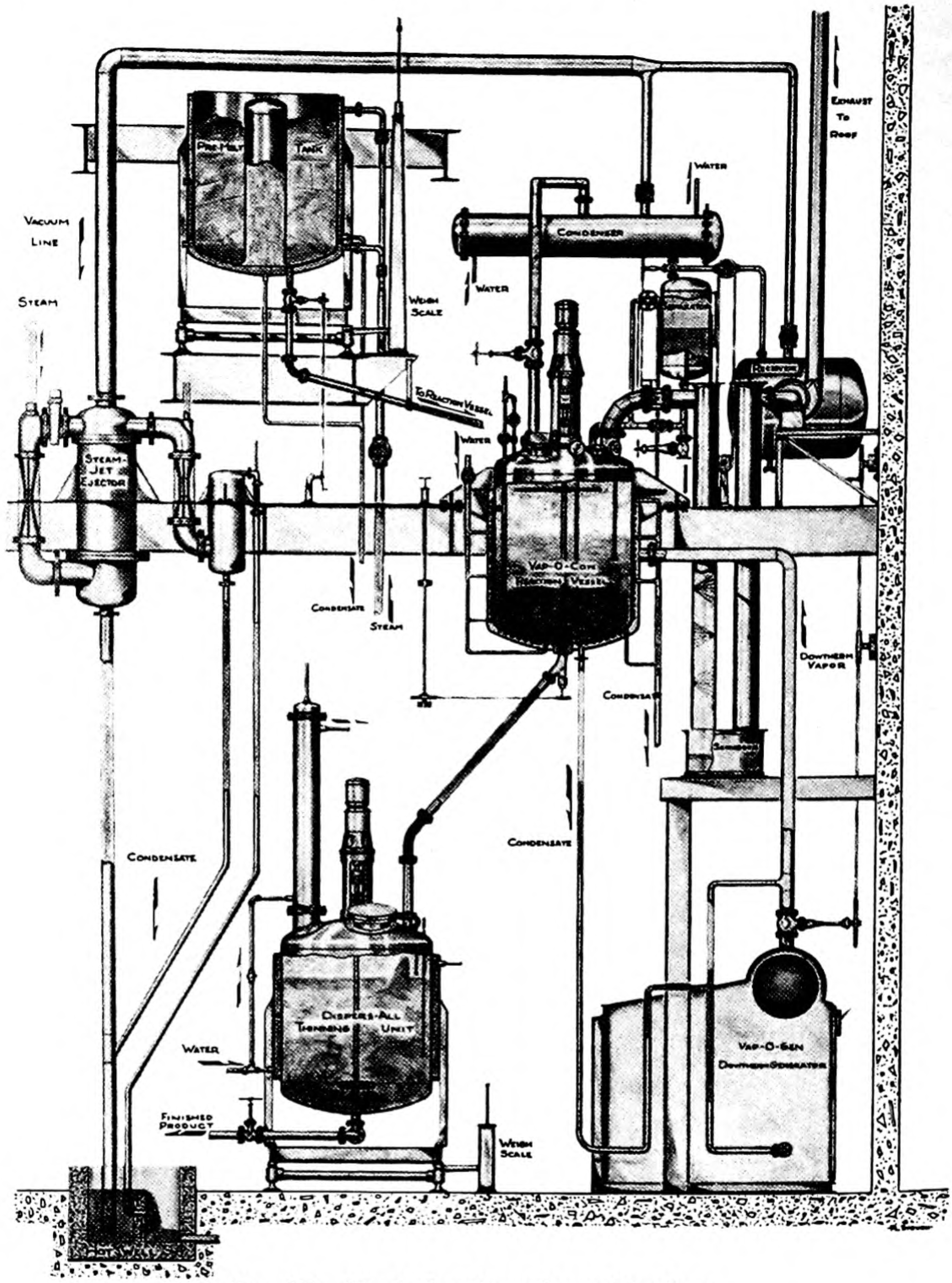


FIG. 37. Typical resin and varnish plant.

the liquids to be introduced accurately by weight, rather than by metering. Scales also afford a method of checking the weight of the batch when finished.

Comparison of Heat Sources

The method of heating is one of the most controversial subjects in the production of varnish. The heat source affects not only the operat-

ing costs, temperature control, cooling facilities, fire hazards, life of the equipment, and capital investment but also the design and selection of the building itself.

Methods of heat transmission include the utilization of coke, coal, natural and artificial gas, fuel oil, electricity, and indirect systems of Dowtherm and oil circulation.

Direct Heating. Portable kettles have been and continue to be satisfactorily heated over coke and coal fires; however, these solid fuels are not generally acceptable for set kettles, because gas, oil, and electricity are easier to handle and to control automatically.

A direct-fired kettle with gas or oil burners under the kettle, in a brick furnace setting, can be installed with the lowest initial cost of any of the available types of heating and probably is the most economical overall production method.

If coke, gas, or oil is used as the fuel, the kettles should be at least 4 to 5 in. above the open fires. Having the kettles closer is not injurious but results in less uniform heating of oils and resins. Coke fires seem to do most harm to the bottoms of varnish kettles, which has been attributed to sulfur compounds and a tendency toward localized overheating.

Gas and oil, in spite of combustion losses, are cheaper than electricity. Direct firing with these fuels is equal or superior in efficiency to indirect heating with them. However, because of the heat to which the bottom of a kettle is subjected and the wide difference in the temperature of the contents and the metal, the possibility of charring or discoloration is always present. Obviously, the temperature control is less accurate by direct fire, owing to the lag in heating or cooling of the brick setting and surrounding furnace walls. The fire hazard is also greater, discharge of the contents is more difficult, and cooling of the batch is more time consuming when a burning fuel is employed.

Gas and oil are also used for stationary or set kettles. The indirect heating of kettles with these fuels is accomplished by means of boilers, vaporizers, furnaces, and circulating systems. Oil circulation for set kettles is easily controlled but is rather expensive to install because kettle jackets are necessary and the oil must be continually recycled with a pump capable of operating at elevated temperatures.

Electric Heating. Before electrically heated kettles are adopted, an analysis of power conditions must be made. For instance, a kettle capable of cooking 500-gal batches may require a load equal to or greater than the current load of the entire plant. Therefore, the present transformer and service conductor capacity must be considered as well as the cost of the new load when it is added to the present consumption.

Many factors in power tariffs or schedules must be studied before

actual power costs can be determined. Utility companies will always cooperate in such a study.

Electric heating involves two general classifications: strip heaters in which the units are clamped directly to the kettle, and the furnace type in which the kettle is installed in a separate furnace. Strip heaters are less expensive and are composed of smaller units with thinner ribbon than that which is used in furnaces. In all electric-furnace operations, the space available, the wattage required, the voltage available, and the amount of heat desired for bringing the batch up to the required temperature will have an effect on the design of the heaters.

Automatic temperature regulators will help to reduce the frequency of burned-out elements. Both types of electrically heated kettles can be made explosionproof. Electric furnaces cost approximately three times as much as strip heaters, but they give more trouble-free service.

Electric heating is advantageous because it is easily controlled, but, unless the cost of power is below average, it cannot compete with other fuels.

Relative Cost of Gas, Oil, and Electricity. Since both gas and oil can be used in the same manner, the choice between them narrows down to availability and the cost on the basis of heating units. The relative efficiency or recovery of usable heat is a debatable subject, but it is generally conceded that gas has some advantage, depending, of course, on local circumstances. Electricity, usually the more expensive fuel from the consumer's standpoint, is viewed in a slightly different light because the power company absorbs the initial losses and delivers heat in the form of kilowatt hours. The only loss in electric heating is by radiation through the insulation of the kettle, whereas gas and oil have combustion and transmission losses also. Therefore, fuel values become competitive in many cases.

An actual comparison of costs has been made in one locality with the following results:

(1)	Fuel oil	6¢ per gal
	Btu content per gallon	135,169
	Cost 1,000,000 Btu's	$0.44
(2)	Gas	50¢ per 1,000 cu ft
	Btu's per cubic feet	1,000
	Cost 1,000,000 Btu's	$0.50
(3)	Electricity	1.5¢ per kwhr
	Btu's per kwhr	3413
	Cost 1,000,000 Btu's	$4.40

The average cost per kilowatthour in moderate-sized plants with 200- to 500-kw demand is between 1.1 cents and 1.3 cents. If the average

rate per kilowatthour is known, this figure can be assumed as the approximate cost of heat per gallon of finished product after thinning the kettle contents, since approximately 1-kwhr is required for heating and holding the temperature during processing. Gas and oil, from the standpoint of fuel only, usually cost between 0.3 cent and 0.4 cent per gallon of finished product.

Dowtherm. Dowtherm vaporizers are used as a source of heat in many modern varnish and resin plants. Dowtherm is a chemical mixture of 26.5 per cent diphenyl and 73.5 per cent diphenyl oxide which is produced by the Dow Chemical Company, of Midland, Michigan.

Dowtherm has a high vaporization temperature capable of reaching 700°F without raising the pressure above 103 psi absolute. At temperatures below the vaporization point, it may be circulated as a liquid for heat transmission.

The specific properties of Dowtherm have been published in an article by M. H. Lewis and D. W. Rudorff.*

> Dowtherm remains fluid at 12°C. and contracts slightly when freezing. The bp at atmospheric pressure is 260°C. At 315°C., the saturation pressure is 30 lbs. per square inch, and at 400°C., it is 150 lb. per square inch. 400°C. is the upper working limit for this and other biphenyl compounds. Above this temperature the compounds begin to decompose slowly.

Information on operating units for liquid-phase and vapor-phase operation is included in the original article.

The following table shows Btu output for various Dowtherm operating conditions:

TABLE 2

Operating Temperature	Operating Pressure	Hourly Btu Output
510°F	3 lb	1,000,000
525°F	7 lb	1,350,000
650°F	54 lb	1,000,000

A Dowtherm installation consists of one or more jacketed stainless steel kettles, a special vaporizer to heat the Dowtherm, and a water-cooled heat exchanger through which liquid Dowtherm is circulated in a closed circuit with the kettle jacket for cooling purposes. Many combinations for grouping the units together are possible which involve special piping, Dowtherm storage tanks, vapor condensers, and control valves.

In buildings high enough to allow 35 ft from the top of the kettle agitator drive to the bottom of the Dowtherm vaporizer, a gravity

* *Engineering,* **151,** 261–264, (1941).

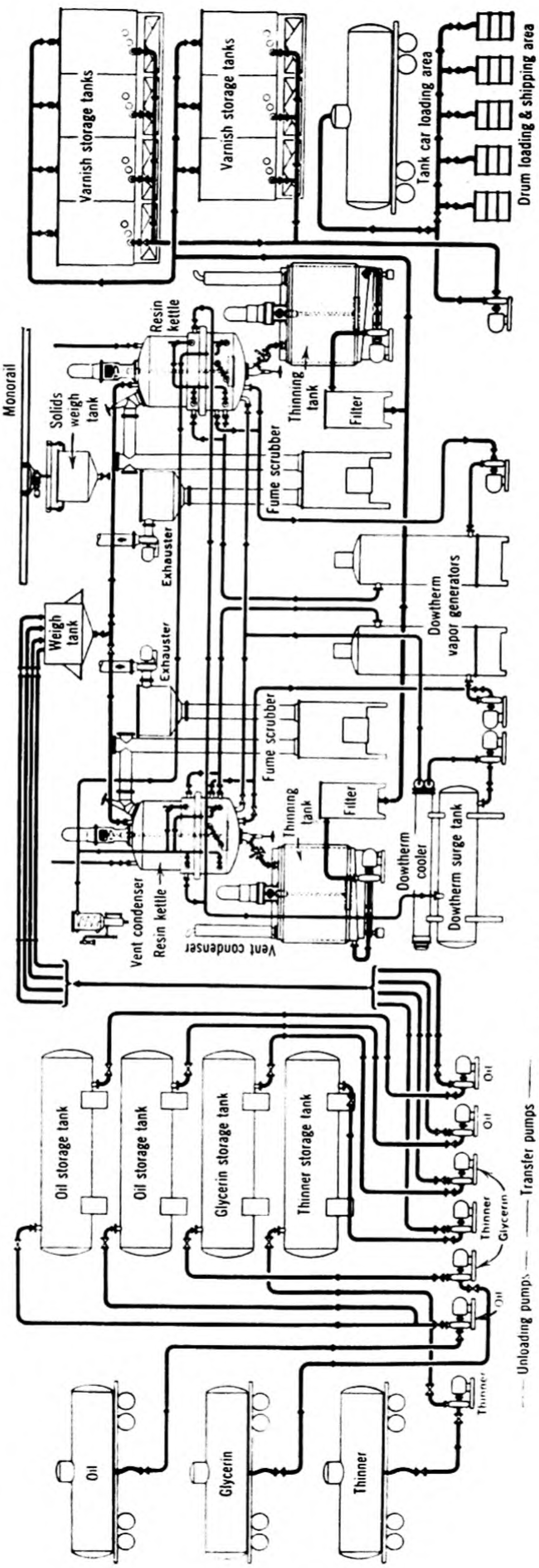


FIG. 38. Flow diagram for resin and varnish manufacture.

return system for the Dowtherm may be installed and the layout is then as simple as an ordinary steam heating plant in a home.

If, however, the plant must be located in a low building, the condensate cannot flow back to the boiler and must be pumped. Since the temperature of the liquid Dowtherm may be 400°F or higher, the pump must be specially designed to operate satisfactorily under these conditions.

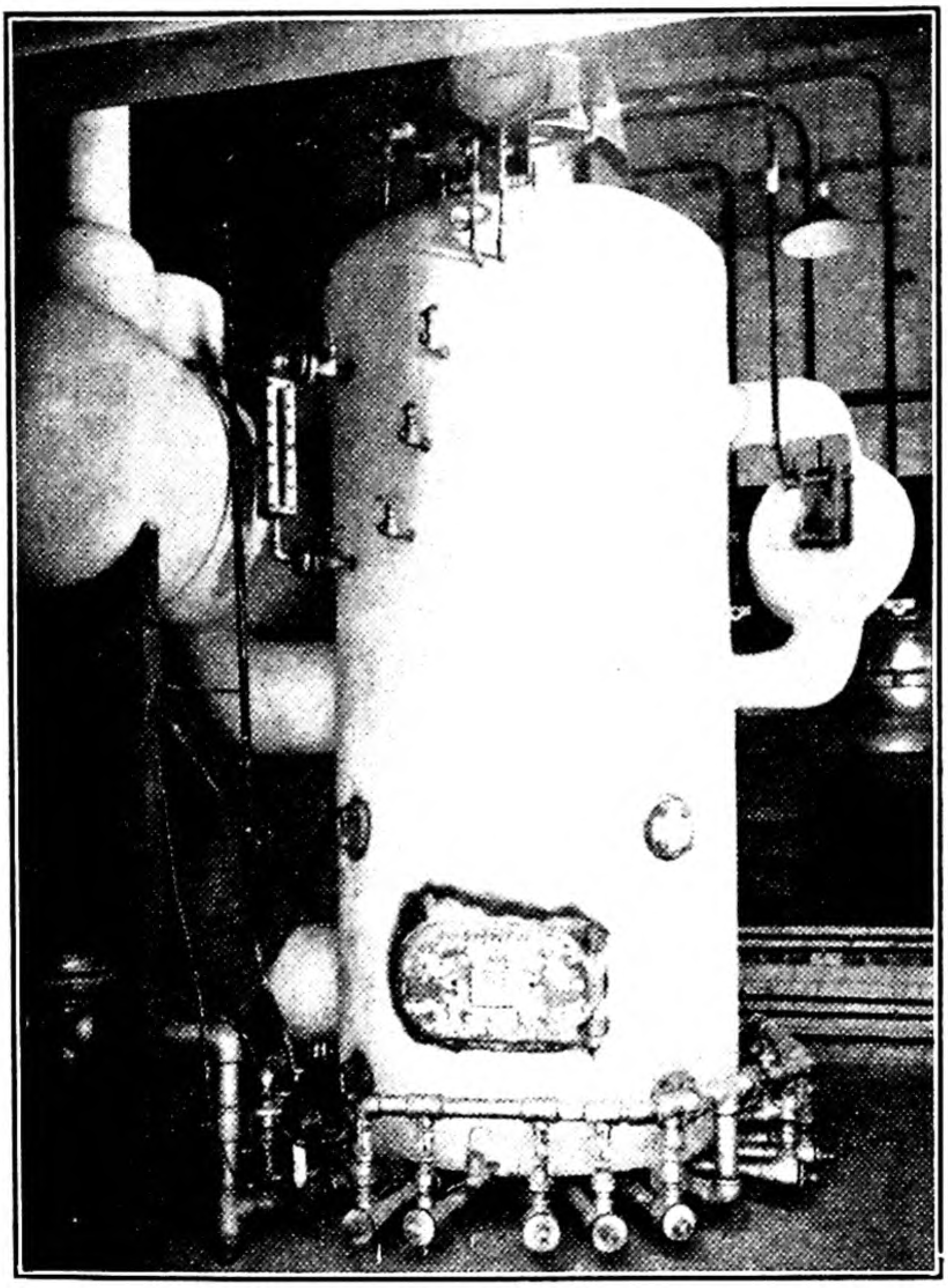


FIG. 39. Dowtherm vapor generator.

The construction and installation of Dowtherm-heated kettles are subjects for separate discussion, but, in order to comply with most state codes, such kettles should be annealed after welding, followed by an X-ray examination of the welds. The shell, heads, and all parts contacting varnishes or resins should be made from stabilized stainless steel. Since Dowtherm is non-corrosive in both liquid and vapor phases, the jacket may be constructed of ordinary steel. Vaporizers when they are used with Dowtherm must also be specially built of all-welded steel construction with all joints X-rayed. Vaporizers are equipped for burning

either gas or oil and are completely furnished with all control and protective requirements for fully automatic operation.

In comparing electricity and Dowtherm, an electric installation usually represents a lower initial cost which requires less space but involves higher operating costs. If space is no problem and the cost of electric energy is high, then the choice should be Dowtherm, heated by either oil or gas. Dowtherm is rated faster for heating than electricity or gas and is somewhat safer to use because the kettles are not in direct contact with high temperatures.

Many details connected with Dowtherm systems are part of good engineering, and the assistance of a competent firm is recommended to assure the most practical application of basic principles.

Fume Recovery

The control of fumes in varnish plants is concerned with the reduction of fire hazards and the improvement of working conditions. There is little evidence that varnish fumes constitute a direct health hazard but they do have an unpleasant odor.

The problem involves the disposal of the decomposition products of resins and oils produced during cooking and the thinners which are evaporated during thinning operations.

Many methods of fume recovery have been proposed and are available which vary from the use of chimneys or stacks to installations of modern fume control systems. Some of the factors which have a bearing on the proper method to adopt will depend on local surroundings; others are presented in the following paragraphs.

Chimneys and Stacks. Uniform withdrawal of fumes by chimneys cannot be attained because the natural draft is so dependent on wind velocity, barometric pressure, and other conditions which vary from day to day and with the seasons. Uncomfortable working conditions and atmospheric pollution in the vicinity of the varnish plant are generally associated with chimneys. The initial cost of stacks, the expense of maintenance, the space required for construction, and the need for more exacting control in the production of materials from modern synthetics have made them less desirable than they were formerly and have encouraged the adoption of fume control systems.

Fume Control Systems. Numerous processes and devices are used in systems for the recovery or disposal of fumes and odors, all of which are based on the following principles:

Condensation and absorption of the fumes by a contact liquid, usually water, and discharging the condensant and solution into the sewer and the non-condensable portion into the air.

Burning of all the fumes by conducting them through a flame.

A combination of the above methods; condensing as much as possible and burning the non-condensable residue.

Disposal of the condensable fumes into the sewer and absorption of the non-condensable vapors with silica gel, alumina gel, or other absorbent.

Disposal of condensable fumes into the sewer and absorption of acidic gases with alkali and alkaline vapors with acid.

Disposal of condensable fumes into the sewer and electrical precipitation of the non-condensable portion.

Condensation may be accomplished by atmospheric cooling, by scrubbing with jets of steam or water, or by contact with a countercurrent flow of water. Chemical methods, especially the use of alkali to neutralize acidic gases, have been proposed and are employed in some plants.

When the fumes from the kettles are burned, they are conducted to a chamber in which gas or oil is burning. One system has been employed in which the fumes are conducted to the ash pit of a coal-fired boiler, after the condensables have been removed. To avoid flashbacks, most engineers recommend the withdrawal of the fumes at a rate of 18 to 20 linear fps, which is faster than the propagation of the flame in the reverse direction. Others hesitate to rely on this method and interpose curtains or barriers between the fire box and the varnish kettle.

Advantages of Fume Control Systems.

Constant removal of fumes regardless of atmospheric conditions.

Comfortable working conditions during cold weather. Obnoxious odors eliminated.

Minimum discoloration of products during cooking process.

Initial cost considerably less than chimneys and stacks.

Small space required for construction.

Fire hazards reduced, especially when melting or running fossil resins.

Production time of fossil resin runs decreased due to removal of volatile reaction products.

Disadvantages of Fume Control Systems.

Periodic cleaning of parts necessary.

Occasional replacement of tubes and parts.

Mechanical attention and adjustments required.

Disposal of residue.

Barneby and McWhorter have described a modern scrubbing system for the control of fumes discharged from varnish, oil, and alkyd resin kettles. The system consists of three major parts: the primary scrubber, in which the easily removable fumes are taken out; the secondary scrubber or jet contactor, in which the fire smoke is agglomerated; and the moisture entrainment separator which takes out most of the scrubbing water carried over by the non-condensable gases.

The primary scrubber consists of a pair of towers, each containing a series of water sprays which wash the gas to remove the readily con-

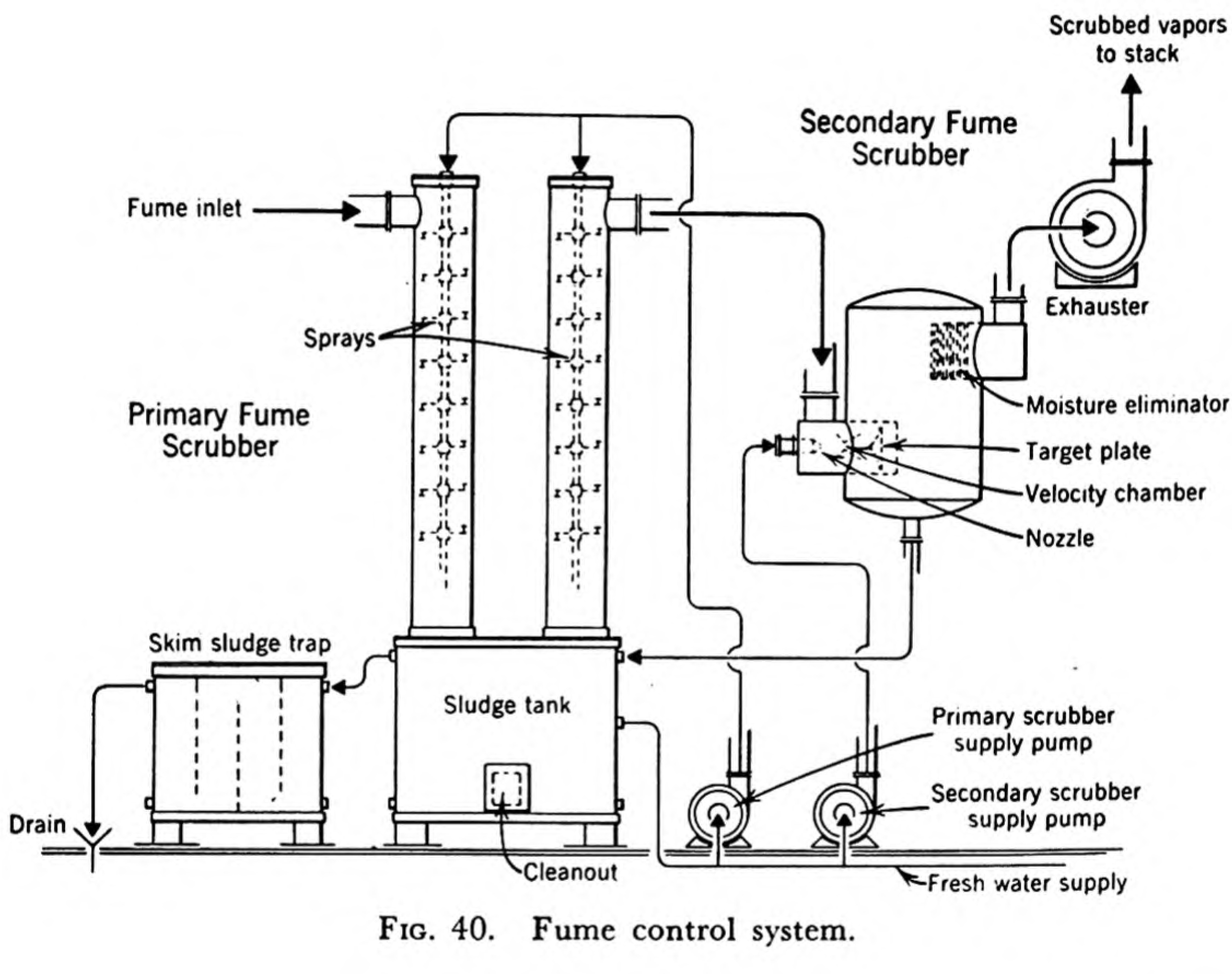


FIG. 40. Fume control system.

densed material and the larger particles of entrained solids. The gas leaving the primary scrubber enters the jet contactors, where it is mixed violently with water by impact, which wets and agglomerates the fine smoke. The water from both primary and secondary scrubbers is accumulated in the sludge tank, and the heavier material is allowed to settle. The clear water is recirculated to the primary scrubber and, with some make-up water, to the jet contactors. The overflow from the sludge tank passes through a skimming tank where the fatty acids are removed.

Basic specifications for the application of the jet contactor system to a varnish fume control problem are:

SCRUBBER CAPACITY REQUIRED

1000-gal closed kettle	300 to 400 cfm
Standard open kettle	800 to 1000 cfm

UTILITY REQUIREMENTS PER 1000 CUBIC FEET PER MINUTE

Water (spray capacity for both towers)	20 gpm (based on no recirculation)
Water	1½ gpm (based on recirculation)
Electric power (exhauster)	3½ hp
Electric power (water pumps)	3 hp
Total electric power	6½ hp

In general, the materials scrubbed out are corrosive in the presence of water. If the *p*H can be kept above 6.0 by a sufficient supply of fresh water, or by the addition of alkali to the recirculated water, the scrubbing system can be made of carbon steel. Otherwise, it should be built of stainless or heavy steel. Brass spray nozzles, piping, and pumps are satisfactory. The collecting ducts ahead of the primary scrubber should be stainless or heavy carbon steel.

Completely fresh water will do an even better scrubbing job than the recirculated water, but the expense may be excessive and disposal of the liquid waste (water containing a large amount of odorous organic material) may be difficult. It is possible to settle or skim off a large part of the organic material; thereby the load on the sewage system is decreased and much of the water may be recirculated.

A good collection system is just as important as a good scrubber. The fume cannot be removed unless it has been collected. For closed kettles the draft must be sufficient to remove all the fume, whether the manway is open or closed, or whether the inert gas is being sparged through the batch. The draft must not be so great as to hinder proper kettle operation or to put too great a load on the scrubber.

Anything that can be done to reduce the amount of fume, or the amount of air drawn along with it, will make the problem of control easier. For example, correct design of hoods over open kettles will be of assistance. A considerable reduction of fumes is achieved by converting all operations to closed kettles. Less entraining air is required, and less fume is produced because oxidation is cut down. The vacuum bodying of oil, in addition to producing a superior product, discharges less fume to be handled by the scrubbing system. The continuous bodying of oils, although not yet considered to be commercially successful, should reduce the amount of fume produced.

The trend in alkyd resin manufacture is toward solvent cooking which

eliminates fumes at the source. In this method the water of reaction is removed, not by high temperature and inert gas sparging, but by cooking with a solvent such as xylol, which removes the water at a lower temperature as an azeotropic mixture. A commercial system for carrying out solvent cooking has been developed wherein solvent introduced into the kettle boils continually and the vapors carry off the water of reaction at a temperature lower than that required in fusion cooking. The solvent-water mixture is condensed, and the solvent is returned to the kettle for reuse. After the reaction is completed, and all the water is carried off, the remaining solvent is distilled into the receiver.

No cure-all exists for fume problems. No single type of apparatus is suitable to handle every kind of industrial vapor, fume, or smoke. Each should be studied, and a solution devised to handle the requirements for the conditions. The difference between a true vapor and a smoke should be kept in mind, since this dictates the basic approach to the problem.

Filters and Filter Aids

Insoluble foreign matter is customarily removed from varnish products with filter presses, centrifugal machines, or by gravity when allowed to settle in storage tanks for long periods of time. Volume production favors mechanical methods of clarification instead of long storage, even for finishing varnishes which are sold and used as transparent coatings.

There are many types of filters, but an efficient filter should meet these general requirements:

It should have sufficient space for a filter aid cake 1 in. thick.

The cake should be built up on a plane so that it cannot break and fall off.

The filter plates should be designed for free and sufficient drainage.

It should be totally enclosed to prevent leakage.

It should be easy to clean.

It should be light in weight and portable for moving to different locations in the plant.

It should filter the batch completely and be dry at the end of the run.

Varnishes and resins should be filtered hot. If convenient, this can be done directly from cooking kettles, but the best method is to pump the varnish into a blending or working tank and filter it as soon thereafter as possible. Filtering on the same day as cooking while the varnishes are still at temperatures ranging from 125° to 250°F is customary.

As a rule the coarsest grade of filter aids available will give satisfactory

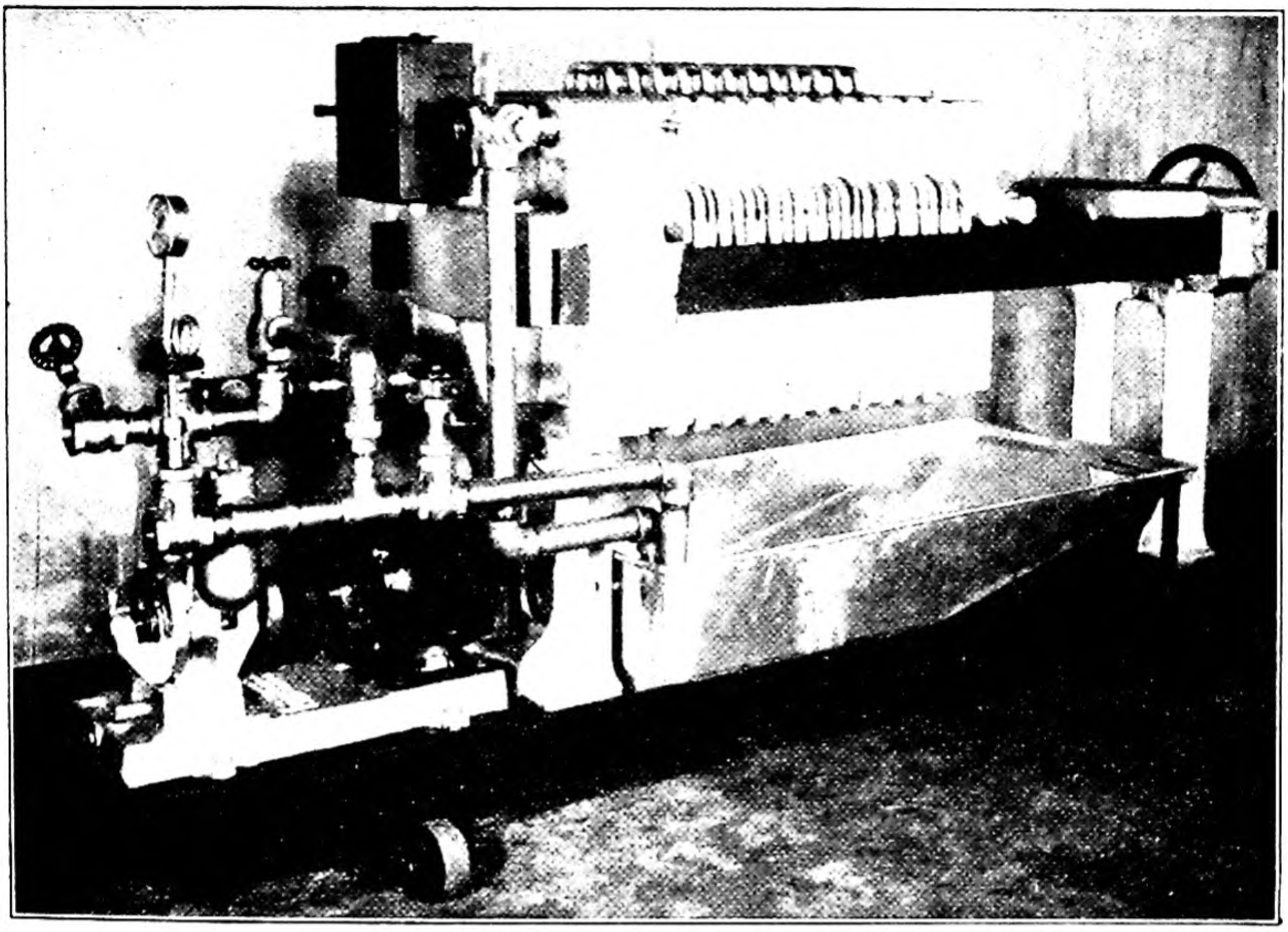


FIG. 41. Plate and frame filter press.

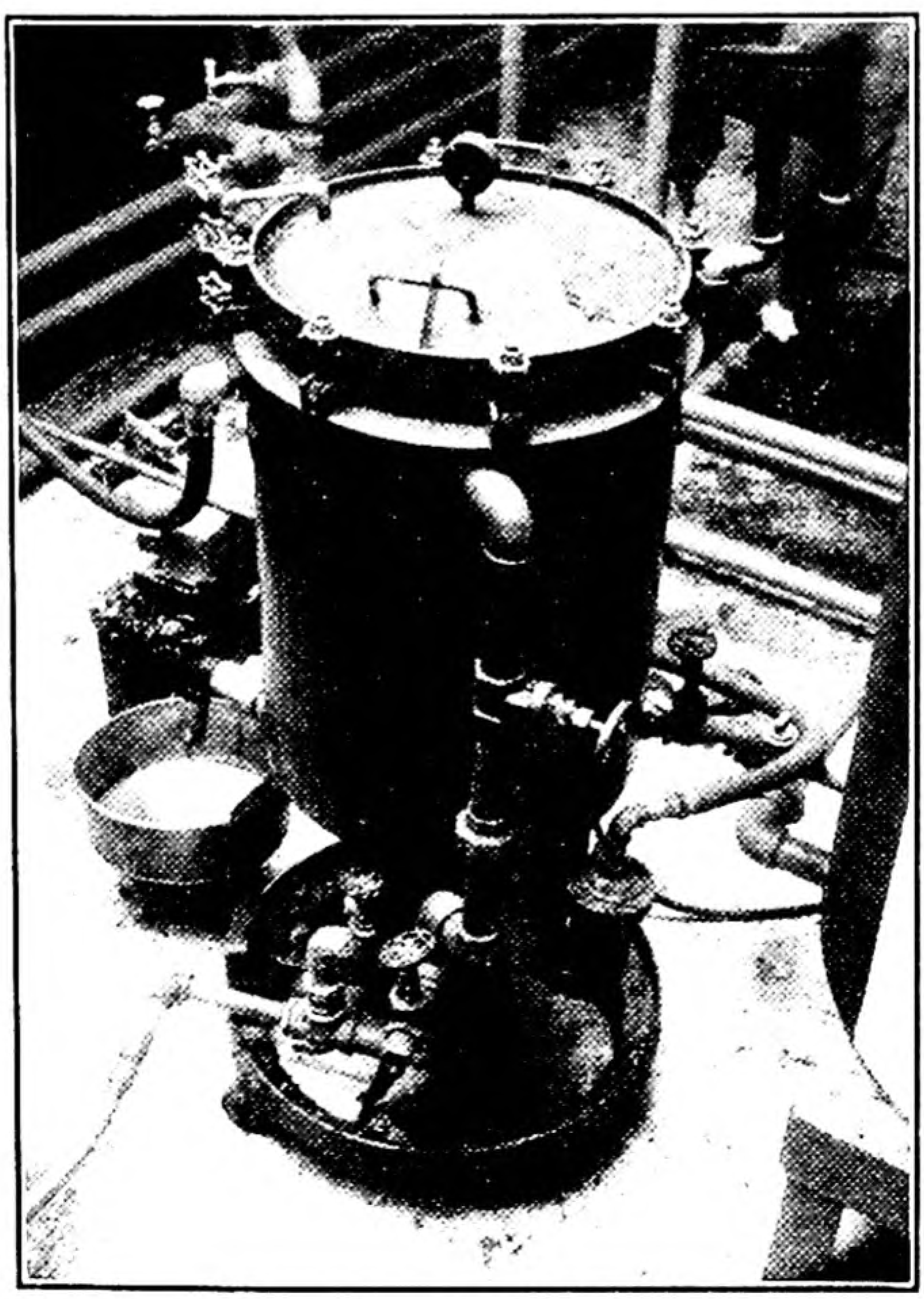


FIG. 42. Sparkler filter.

clarity with all types of varnishes and resins, although some alkyd resins require a finer grade.

The amount of filter aid may vary from 0.05 to 1.5 per cent by weight of the liquid vehicle. Most synthetics are filtered with 0.25 per cent to 0.5 per cent, and natural gum varnishes usually require 0.5 to 1 per cent of filter aid by weight.

For the simplest, most economical method of filter cleaning, filter paper is superior to cloth. If the press is designed so that breaking of

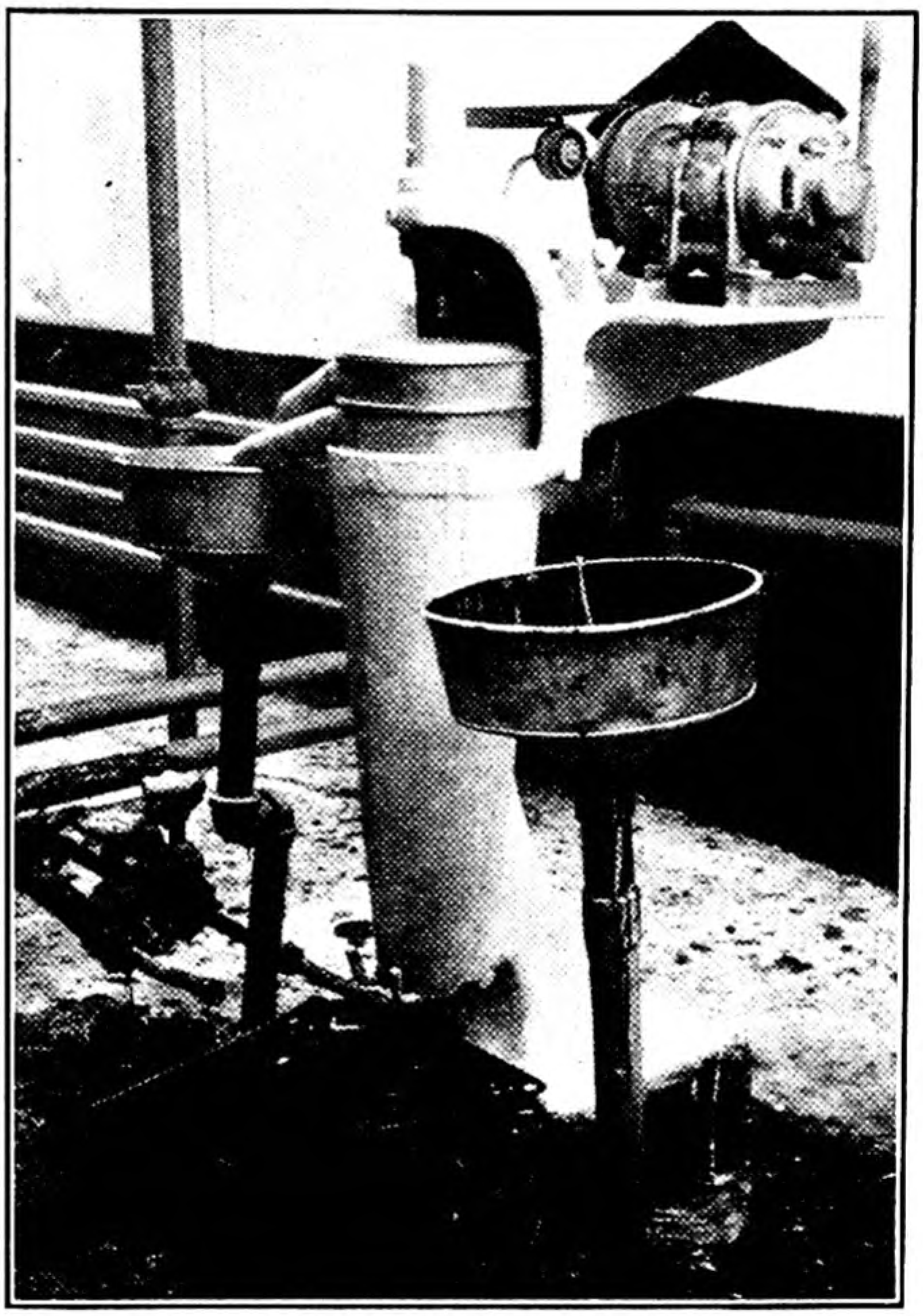


FIG. 43. Sharples centrifuge.

the paper can be avoided without the use of cloth, the filter may be easily cleaned by peeling off the paper with the spent cake; it is then destroyed.

Centrifuges. Centrifuges clarify varnishes quickly, economically, and, as a rule, satisfactorily. The motor-driven bowl of the centrifuge generates a separating force which may be as much as 13,000 times greater than the force of gravity. Varnish is fed into the bowl and subjected to this enormous separating action (centrifugal force), and, when discharged from the bowl, it is clarified and free of foreign particles. For handling small batches of various products, a portable centrifuge offers

many advantages. However, stationary models are more satisfactory for large runs of relatively few types of materials.

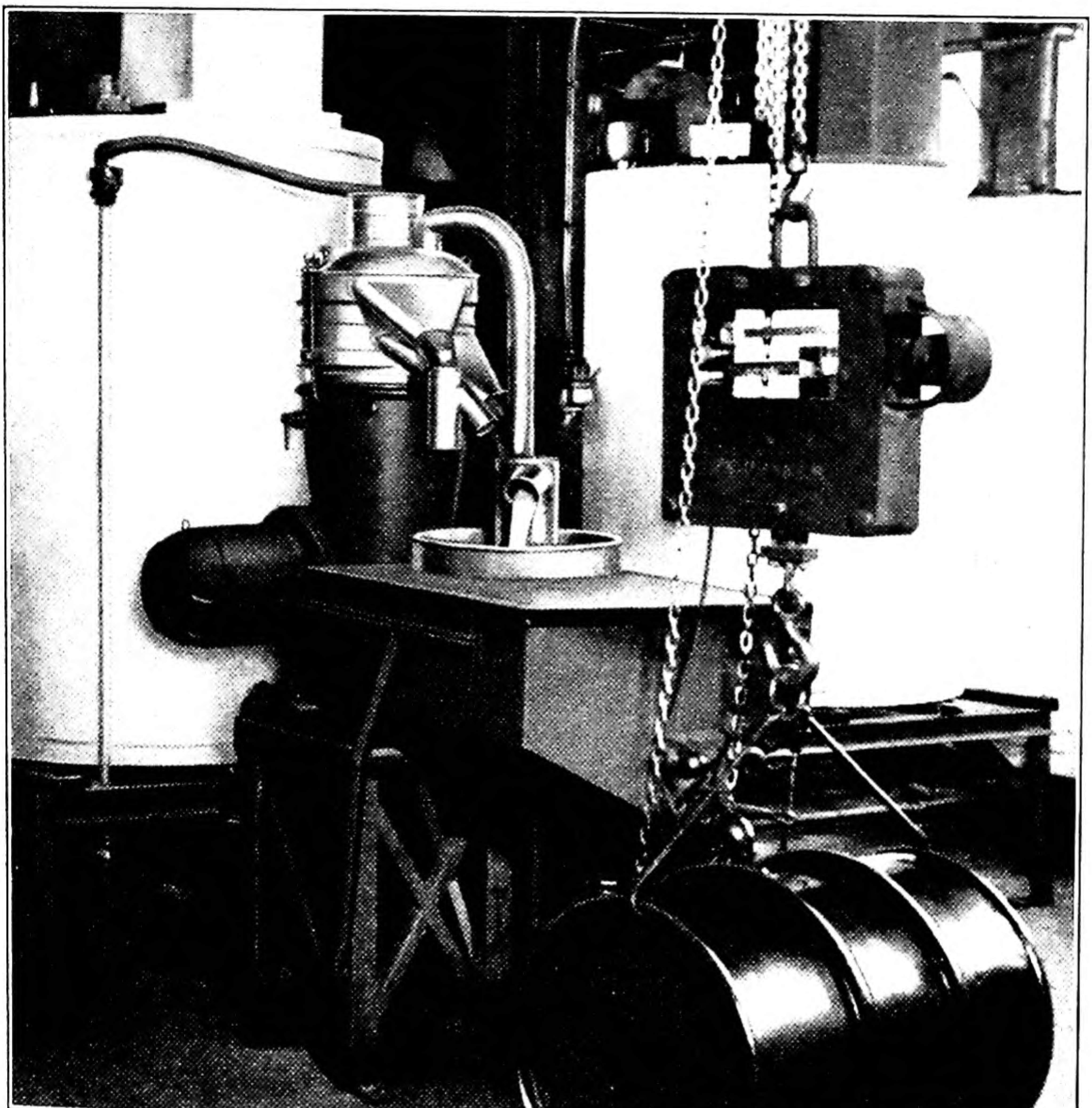


FIG. 44. DeLaval clarifier.

OFFICIAL DIGEST BIBLIOGRAPHY

Badger, W. L., "Stationary Closed Kettles in Varnish Plants," p. 1030 (Dec., 1948).

Barneby, H. L., and C. J. McWhorter, "Fume Control in Varnish Manufacture," p. 437 (Dec., 1948).

Beattie, J. C., "NEHCO Process Manufacture of Varnish and Bodied Oils," p. 176 (June, 1930).

Byron, T. F., "Some Aspects of Vehicle Manufacturing in Set Kettles and Stills," p. 359 (June, 1947).

Carleton, R. A., "Electrical Heat in Varnish Manufacture," p. 6 (Mar., 1928).

Carleton, R. A., "Electric Heat in the Paint and Varnish Industry," p. 40 (Dec., 1929).

Cleary, W. D., "Centrifugal Clarification," p. 5 (Feb., 1926).

Cunningham, C. E., "Controlled Heat Release for Processing Chemicals," p. 526 (Aug., 1949).

Dittmer, J. C., "Fume Scrubber—Effective on Linseed Oil Kettles," p. 516 (Sept., 1947).

Elliott, C. R., "Removal of Fumes in Varnish Thinning," p. 305 (Nov., 1934).

Fuller, W. D., "Use of Gas in the Manufacture and Application of Resinous Products," p. 989 (Oct., 1932).

Gilbert, H. G., "Enclosed Radiant Combustion," p. 1073 (Dec., 1932).

Glidden, W. T., "Clarification and Filtration," p. 5 (Feb., 1920).

Graff, W., "Varnish Fires," p. 6 (Jan., 1925).

Hanley, J. R., "Proportioning Equipment as Related to Weight Measurement," p. 1027 (Dec., 1948).

Hock, A., "Varnish Kettles From the Manufacturer's Viewpoint," p. 120 (Mar., 1940).

Jauch, W. M., "Catalytic Fuel Oils and Electronic Varnish Fire Controls," p. 433 (Oct., 1946).

Jauch, W. M., "Heat Systems and Controls for Portable Varnish Kettles," p. 255 (June, 1946).

Jauch, W. M., "Radiant and Direct Oil and Gas Fired Autoclaves," p. 178 (Mar., 1947).

Jares, J., "Fume Disposal Systems," p. 367 (Oct., 1945).

Karnopp, A. W., "Stackless Varnish Plants," p. 18 (Nov., 1924).

Klopfenstein, G. J., "Proportioning Equipment as Related to Volume Measurement," p. 1025 (Dec., 1948).

Loney, D., "Oil Fires," p. 17 (May, 1929).

Montreal Club, "Layout of a Modern Paint and Varnish Plant," p. 395 (Nov., 1945).

New York Club, "Report on Fume Control," p. 7 (Dec., 1924).

Perry, R. S., and R. W. Webster, "Fume Recovery Systems," p. 2 (Nov., 1920).

Perry, R. S., "Varnish Plants," p. 2 (May, 1923).

Philadelphia Club, "Design of a Modern Varnish Plant," p. 414 (Oct., 1946).

Russell, T. S., "Chemical Engineering Factors Involved in Heat Bodying and Equipment Trends," p. 19 (Jan., 1946).

Shuger, H. H., "On the Way to Varnish Plant Modernization," p. 315 (May, 1944).

Sperry, D. R., "Various Kinds of Filters in Use Today," p. 3 (Apr., 1924).

Spillman, A. D., "Developments in the Application of Power and Its Use in Heating Varnishes and Oils," p. 1043 (Nov., 1932).

Sutton, M. and A. Bond, Jr., "Application of Votator Heat Exchanger in the Paint and Varnish Industry," p. 300 (June, 1949).

Thurmond, C. D., "The Manufacture of Alkyd Resins," p. 181, (Apr., 1945).

Tonkonogy, A., "Design and Operation of Direct Fired Units for Resin, Varnish, and Oil Processing," p. 510 (Sept., 1947).

Williams, H. V., "Modern Resin and Varnish Cooking Equipment," p. 351, (Aug., 1946).

ADDITIONAL FEDERATION OF PAINT AND VARNISH PRODUCTION CLUB PAPERS

Chicago Club, "A Practical Varnish Plant," *NPVLA Sci. Sec. Cir.*, p. 842 (Nov., 1929).

Toronto Club, "Comparative Study of Varnish Fires," *NPVLA Sci. Sec. Cir.*, p. 823 (Nov., 1929).

CHAPTER 4

PRODUCTS

INTRODUCTION

The basic intention of this chapter is to describe the more common products of the industry and to provide adequate references for others.

The discussion that follows reflects practical experience, expressed in non-technical terms as far as possible, and reviews available literature in order to present a source of general information for plant men who require a working knowledge of raw materials and finished products.

The paint industry probably produces more items of different physical properties than any other field of manufacturing. Paint is only one product among hundreds of coatings that are made for all types of applications to cover a great variety of surfaces. The term paint usually refers to the coating which is applied on houses and accounts for a large proportion of the total gallonage of the industry, but there are many paint products which are applied to other surfaces in considerable quantities. These include the industrial coatings that are made to meet definite conditions of application, wear, appearance, color, and other requirements for specific purposes.

Paints differ from enamels in the amount of gloss or sheen, and in the type of vehicles used. Paint films are soft and elastic and ordinarily low in gloss, whereas enamels are hard and tough and based on vehicles containing less oil. Paints usually dry more slowly than enamels and are adaptable to both interior and exterior surfaces.

Another class of surface coatings, the transparent varnishes, are combinations of oils and resins in solvents. Still another class of finishes, known as lacquers, are entirely different from any of the others in that they contain nitrocellulose or other soluble cellulose materials. They dry very rapidly by evaporation of solvents, such as alcohols, aromatics, esters and ketones instead of the usual hydrocarbon solvents contained in other paint products. Lacquers include about ten or twelve main classes and an unlimited number of special types. They may be transparent or pigmented and are usually identified by the characteristic odor of solvents, exceptionally fast-drying properties, and the hardness and lack of fullness of the dried films.

Before describing the products of the paint industry, a brief summary will be given regarding the types of raw materials employed, along with a description of their physical properties. Listed among the raw materials are the white and colored pigments, solvents, oils, plasticizers, driers, and the natural and synthetic resins. Only a general summary can be included since the almost limitless number of raw materials makes it impossible to cover all in detail. The average plant uses roughly about 200 kinds of pigments, and 50 to 100 varieties of oils, resins, clear vehicles, and solvents; each has some distinct property, but all are susceptible to classification within certain limits and these will be described. In this way the reader will acquire a general knowledge of the raw materials which are used for specific purposes.

Raw Materials

Pigments. General information regarding the ordinary pigments involved in the manufacture of paints and allied products can be obtained more readily from a brief tabulation of their properties than from individual description.

Oils. *Linseed oil* which is extracted from flaxseed is the most common of all the drying oils and one of the first oils used in protective coatings. Even in the raw state, with the addition of a little metal drier, linseed is an excellent drying oil. Although the prime requisite for a paint oil is satisfactory drying, the oil should possess the correct acidity, viscosity, and color for specific purposes. Low-acid-number oils are generally non-reactive and may be used with reactive pigments; high-acid oils are good grinding oils, but care must be exercised in mixing them with basic pigments. Low-viscosity oils make good brushing paints but do not flow so well as those with heavier body. For white coatings the color of the oil should be as light as possible, whereas for darker coatings color is not too important. Most raw oils must be refined for the manufacture of varnishes by bleaching and removal of objectionable matter termed "foots."

The iodine value of a good drying oil should be at least 160, and any oil between this figure and 130 is considered semidrying. *Soybean oil* is an example of a semidrying oil, with an average iodine number of 135. After processing to improve its drying properties, it is used alone in large quantities or in combination with other drying oils. Oils such as *castor,* having iodine values below 130, are non-drying and are useful only as softeners for increasing the flexibility of brittle films, unless they are converted into drying products, such as dehydrated castor oil.

Linseed oil may be heated or air blown to practically any viscosity. Its color can range from very dark to almost colorless, and the acid

Name	1 % Reflectance	2 Tint	3 Oil Absorption	4 Hiding	5 Reactivity	6 Bulks	Properties and Uses
Whites							
Antimony oxide	97	325	13	24	No	2.10	Non-toxic, chalks slowly, used in fireproof paints
Lithopone	95	260	16–18	27	No	2.79	70:30 barium sulfate-zinc sulfide, general purpose pigment
Titanium dioxide (anatase)	95	1250	20–25	115	No	3.09	General use
Titanium dioxide (rutile)	95	1600	18–22	160	No	2.86	Maximum hiding
Titanium-calcium (anatase)	96	460	22	47	Very slight	3.69	30:70 titanium dioxide-calcium sulfate, used for interior finishes
Titanium-calcium (rutile)	96	600	15–20	63	Very slight	3.69	Similar to above but with higher hiding
Titanium-barium (anatase only)	96	400	14–16	44	No	2.86	30:70 titanium dioxide-barium sulfate, used in house paints and primers
White lead (carbonate)	95	100	10–14	15	Slight	1.79	Pigment for house paints, toxic, reactive, good repaint surface, darkens on exposure
White lead (sulfate)	94	85	10	13	Very slight	1.88	Similar to the carbonate but less reactive
Leaded zinc oxide	91	170	12	20	Yes	2.03	65:35 zinc oxide-lead sulfate, used with other pigments for house paints
Zinc oxide	96	200	16	20	Yes	2.14	Generally used with other pigments, aids drying, gloss, and gloss retention
Zinc sulfide	95	850	22	58	Slight	3.00	Used for high hiding and with other pigments
Inerts (Non-hiding pigments)							
Asbestine or talc	90	0	25–35	0	No	4.21	Magnesium silicate, needle-like, minimizes cracking of films and hard settling

Name	1 % Reflectance	2 Tint	3 Oil Absorption	4 Hiding	5 Reactivity	6 Bulks	Properties and Uses
Inerts (Non-hiding pigments) (*Continued*)							
Barytes	95	0	10	0	No	2.73	Barium sulfate (natural), very heavy, settles badly
Blanc fixe	97	0	10–14	0	No	2.75	Precipitated form of barytes, finer, more expensive
China clay	86	0	30–45	0	No	4.62	Used in primers, undercoaters, emulsion paints, settles
Gypsum	88	0	16	0	Slight	5.11	Used in sealers and undercoaters for porous surfaces
Mica	70	0	30	0	No	4.14	Flat, plate-like particles, retards action of sunlight, used to reinforce films
Silica	91	0	25–30	0	No	4.53	Provides adhesion for subsequent coats
Whiting	94	0	15–20	0	Slight	4.43	Calcium carbonate, used in flat wall paints and emulsion paints for dry hiding

1. Per cent reflectance, G filter reading Hunter Reflectometer, for white pigments only.
2. Tinting strength expressed in terms of white lead (= 100), for white pigments only.
3. Oil absorption ASTM D-281-31, lb oil per 100 lb pigment (average figures).
4. Square feet per pound pigment.
5. Reactivity with acid vehicles.
6. Gallons per 100 lb of pigment.

number can be controlled to govern the reactivity of the oil. Raw linseed oil and a combination of raw and bodied linseed oils are customary for house paints; an almost neutral refined linseed oil is considered the best grade for varnish production. With proper treatment, linseed oil can be made to dry in as short a time as 4 hours.

Tung or China wood oil, an imported oil which is now produced in limited quantities in the southern part of the United States, is seldom used alone as a paint oil, but it is extremely important in the manufacture of varnishes. It has the property of becoming very thick and gelling rapidly when heated; not in hours, as is required to body linseed oil,

Name	Tint*	Oil Absorption	Hiding	Reactivity	Bulks	Properties and Uses
Blacks						
Carbon	1	100–150	2400	No	6.63	Many types, from gray to jet black
Graphite	36	low	195	No	5.24	All grades of fineness, crystalline, for structural coatings
Lampblack	5	148	2400	No	6.74	Similar to carbon black but has blue undertone
Mineral black	36	40	290	No	varies	All grades, with varying carbon content and color
Bone black	35	45	—	Yes	4.60	Used for fillers and eggshell coatings
Black iron oxide	12.5	22	550	No	2.43	For tough resistant coatings
Blues†						
Iron blues (Chinese, Milori, Prussian)	12†	55	500	Yes	6.49	Differing undertones, green or red
Phthalocyanine	20	30	—	No	7.32	Strongest, most permanent blue, acid-alkali resistant
Toners						
Indanthrene	6	38	—	No	6.19	Durable, acid-alkali resistant
PTA Victoria	40	55	—	Yes	5.22	Tungstate blue, bleeds, poor acid-alkali resistance
Violet	48	50	—	Slight	5.36	Tungstate purple, medium acid-alkali resistance, bleeds
Ultramarine blue (red and green shades)	1	30–35	30–40	Slight	5.17	Poor acid resistance, fair durability
Greens						
Chrome greens	Varies	20–40	1000	Yes	2.5 (light) 3.6 (medium)	Made from iron blue and lead chromate, light, medium, dark Poor acid-alkali resistance, durable
Chromium oxide	Weak	17	580	No	2.36	Acid-alkali resistant, durable

* Tint indicates amount required to approximate 1 part carbon black.

† Tinting strength based on ultramarine blue = 1.

Name	Tint	Oil Absorption	Hiding	Reactivity	Bulks	Properties and Uses
Greens (Continued)						
Chromium hydrate	Weak	52	90	No	3.23	Similar to oxide but much lower hiding; bright color
Phosphotungstic lake	Medium	45–55	475	Yes	3.14	Good acid-poor alkali resistance, bleeds in ketones
Phthalocyanine	Strong	38	—	No	6.09	Very strong, durable, resistant, non-bleeding
Reds						
Alizarine	Weak	30–60	60–120	No	Varies	Fair durability, poor acid-alkali resistance, bleeds
Cadmium	Weak	17	75	No	2.50	Durable, poor acid-good alkali resistance, low hiding, high heat resistance
Indian red	Medium	16–20	850	No	2.44	High-hiding, heat-resistant, blue shade iron oxide
Iron oxides	Depends on % iron	12-25	Varies	No	2.72	Percentage iron content controls hiding and strength Excellent heat resistance
Lithols	Strong	40–50	160	No	Varies	Poor durability, fair acid-alkali resistance, bleed
Paras	Strong	40–50	300	No	8.06	Poor durability, good acid-alkali resistance, bleed
Paras (chlorinated)	Strong	32–40	200	No	7.36	Good durability, excellent acid-alkali resistance, bleed
Red lead	Weak	7	70	Yes	1.35	Metal primers
Toluidines	Strong	40	250	No	8.58	Excellent durability, good acid-alkali resistance, slight bleed
Yellows						
Cadmium	Weak	17	70	No	2.80	Poor acid-good alkali resistance, excellent durability
Chrome orange	Strong	10	60	No	1.75	Poor acid-fair alkali resistance, excellent durability

Name	Tint	Oil absorption	Hiding	Reactivity	Bulks	Properties and Uses
Yellows (Continued)						
Chrome yellows	Medium	20	75–100	No	2.10	Lead chromates, fair acid-poor alkali resistance, fair durability
Ferrite yellow	Strong	30–50	105	No	2.86	Excellent durability, excellent acid-alkali resistance
Hansa yellow	Strong	45	—	No	9.45	Organic, good acid-alkali resistance, good durability, bleeds
Molybdate orange	Strong	26	250	No	2.27	Fair durability, fair acid-poor alkali resistance
Zinc yellow	Weak	24	50	No	3.39	Good durability, poor acid-alkali resistance

but in a relatively few minutes. The cooking process, therefore, must be carefully controlled to secure the proper body and to develop the full properties of the oil without overheating. Tung oil produces excellent waterproof varnishes with better alkali resistance than can be produced from other natural oils.

Oiticica oil is imported from South America and is similar to tung oil in its general properties, although it is not quite so alkali resistant nor so durable. The use of oiticica oil is more dependent on market conditions and the availability of tung oil than on its own individual characteristics.

Soybean oil, one of the most recent oils to be commercially available, is now produced in great quantities in the Middle West. A semidrying oil of good color, it is used in varnishes, particularly in light-colored alkyd synthetic varnishes. It is a low-acid oil and provides good non-yellowing properties to the aged films of white and light-colored finishes.

Other oils, such as *sardine, dehydrated castor, perilla,* and various synthetic oils are used by the industry either as replacements for those which have been described, depending on economic conditions, or to take advantage of the peculiar characteristics which they possess.

Tall oil, a refined product derived from the paper industry and actually a mixture of rosin and fatty acids, is consumed in considerable quantities by the paint industry. When esterified or treated chemically, it is useful in the production of low-cost varnishes for general utility.

Driers. All the drying oils used in the coating industry require

catalysts to shorten the drying period. Any oil with an iodine value above 160 will eventually dry by itself in several days, but, to be practicable, the drying period should be 24 hours or less. In order to reduce the length of time required for an oil film to dry, it has been found that certain metals, notably lead, manganese, and cobalt, definitely act as accelerators. The metal must first be put into solution by reaction with oil-soluble acids, such as naphthenic, resin, or fatty acids. It is then miscible with oil or varnish which is being prepared for application. It is usually found that a combination of driers, such as lead-manganese, lead-cobalt, or a mixture of the three, is more effective than a single drier. Care should be taken to avoid an excess of drier, since too much may actually retard the drying time of the film instead of accelerating it. For example, linseed oil normally requires about 0.2 per cent lead and 0.02 per cent manganese; house paints, 0.2 per cent lead, 0.02 per cent manganese, and/or 0.01 per cent cobalt; varnishes, 0.3 per cent lead and 0.03 per cent cobalt; and alkyd varnishes, 0.4 per cent lead and 0.03 per cent cobalt. Drier figures generally refer to the percentage of metal on the basis of oil content.

Lead driers are pale in color but have poor drying qualities when used alone. When manganese and cobalt are added, either separately or with lead, marked improvement in dry is experienced, but the percentages must be carefully balanced and minimum amounts employed to avoid unpleasant odor and poor durability. Certain pigments, such as organic reds and carbon blacks, are known to interfere with the mechanism of drying, whereas others, notably those which contain lead and zinc, will improve the drying characteristics of the film after application. Manganese used in combination with lead produces fast-setting, through-dry films; cobalt, the most powerful drying agent, produces top dry and wrinkling, unless used in small quantities and in conjunction with lead or manganese. Soluble forms of iron, calcium, and zinc are also used, chiefly as auxiliaries with the other metals or in special applications.

Resins. Resins are coating materials that are soluble in oils or solvents, some of which dry to transparent films, whereas others are quite opaque. There are numerous grades of resins, ranging in color from water white to jet black. The melting point range may vary from room temperature to 400°F, and the acid number may vary from neutral to 160 or above. Solubility in specific solvents is one of the most important features of a resin, since the use of a solvent with other ingredients and application as a film depend on some form of solution or dispersion. All resins should be soluble in one or more of the following liquids: petroleum or coal-tar thinners, ketones, esters, alcohols, and oils. Knowledge of their compatibility with other materials will ultimately de-

termine their adaptability for particular products. Many resins are used alone as solutions in hydrocarbon solvents, whereas others are used as solutions in oils and suitable solvents or in combination with other resins, modifying agents, plasticizers, and driers. Some of these solutions will air-dry; others require heat to produce a film. The physical properties must be kept in mind in choosing a resin for a specific purpose.

Resins are classified as natural or synthetic. The natural resins were at one time the only types available and offered a limited choice for color and solubility. There were many grades with respect to size and color. Each piece of fossil resin was selected and scraped and kept as uniform as nature permitted. With the gradual exhaustion of natural sources, synthetic resins were developed. These are satisfactory replacements and are more uniform and dependable. Dammars, East Indias, Congos, copals, and kauris are being replaced by the more versatile synthetics. Both dammars and East Indias are soluble in hydrocarbons, and the copals, though insoluble in hydrocarbons, are soluble in alcohols and ketones. Raw Congo gum, however, is insoluble in all oils and solvents and must first be heat-processed to become soluble. Kauri gum, soluble in alcohols and ketones, and insoluble in hydrocarbons, is heat-processed also to blend with oils and to produce varnishes.

The importance of *shellac* and *gilsonite* as natural materials which have unique properties must not be overlooked. Shellac gum, when dissolved in alcohol, is used extensively on floors and furniture and frequently as the first coat on new wood over which other finishes may be applied. Gilsonite is a black resin found in Utah and is soluble in vegetable oils and petroleum thinners; it is the basic ingredient for many industrial coatings such as air-dry asphaltums and black baking japans or enamels. Combinations with *petroleum asphalts* are common.

None of these natural resins offers a very wide range of possibilities. It was the introduction of synthetic resins which really paved the way for the modern conception of protective coatings in the industry. The limitless number and variety of synthetic resins have resulted in the production of coatings that will meet every requirement. Synthetic resins may be obtained in all degrees of color, hardness, reactivity, durability, and solubility. Thus the problem of choice is more difficult than that of finding a source of supply.

Although *rosin* is a natural resin, it is used in combination with many synthetics as a modifier and requires special description. Rosin itself is a fairly hard, high-acid resin, soluble in nearly all solvents; it varies in color from pale straw to very dark amber. The importance of rosin does not lie in its own physical properties but is directly related to the products which are derived from it.

The first resin to be derived from rosin was limed rosin, made by reacting rosin with lime flour or calcium hydroxide, thus producing a low-acid resin with higher melting point and much harder than the original rosin. This *hard rosin*, or *limed rosin*, as it later was called, had many improved properties as compared with the raw rosin, including better dry and decreased acidity, and it contributed to the manufacture of harder varnishes. The next step in the advancement of resins was the production of *ester gum* by reacting rosin with gycerol. This gave a high-melting resin with low acidity, pale color, better water resistance, and good durability. Low-acid ester gums (resins) are still used in the production of varnishes for good water resistance, durability, and low reactivity. For use with lacquers, high-acid-value grades are made that are soluble in alcohols and compatible with nitro-cotton. Many other types of rosin esters are now available with definite characteristics depending on their compositions.

The first real synthetic resins were the phenol formaldehyde types, usually called *phenolics* which became available commercially about 1925. Originally these phenolics were produced only in one or two grades, and considerable trouble was experienced in cooking and using them. At the present time, there are numerous grades, each with well-recognized properties. The most durable and resistant are the 100 per cent pure oil-reactive phenolics which produce varnishes of extreme durability, water resistance, chemical resistance, and toughness. Varnishes made from this resin make superior spar varnishes, water-resistant primers, and durable enamels, highly resistant to weathering. The pure heat-reactive phenolics are used mainly to fortify ester gum and rosin varnishes, to improve the water and chemical resistance, and to increase durability. They are also cooked to produce tough, well-cured insulating varnishes. Other oil-modified phenolics are used to produce tough metal coatings with good adhesion. Resin-modified phenolics, with high phenolic content, produce coatings of excellent water resistance and good through drying and are used in floor varnishes, architectural enamels, and general-purpose coatings. Special phenolics, which combine good hardness and cold-check resistance with resistance to water and alcohol, are made for the lacquer industry. These phenolics make good furniture lacquers because they have excellent sanding properties and are also excellent for primers. A special grade of liquid phenolics is employed for can coatings, to form baked linings for tin cans which are resistant to alcohol and foods. These finishes are superior to most oleoresinous coatings and are equaled only by certain vinyl resins.

Alkyds were introduced to the paint industry somewhat later than the phenolics and are now used in tremendous quantities for the manu-

facture of coatings. Glyceryl phthalate resins were the first to be generally used, but a number of other types have been developed such as the pentaerythritol alkyds and those made with dibasic acids other than phthalic. Alkyd resin varnishes are pale, low-acid, and durable and can be made with varying oil content. They can be air-drying or non-drying, depending on the type of vegetable fatty acids employed and the per cent of phthalic or other acid that they contain. The short-oil alkyd, mixed with urea or melamine resins, forms the base for hard white enamels generally used on refrigerators. The medium-oil alkyd is used in pigmented coatings, where great durability as well as good gloss retention and appearance are important. The long-oil alkyd is used in architectural white enamels where good brushing and appearance, as well as durability, are required. Alkyds are also employed in the production of lacquers to increase the gloss and durability of the cellulosic solutions. In combination with other hard resins, such as chlorinated rubber and the maleics, modified alkyd solutions of unusual properties have been produced for many types of finishes.

Coumarone-indene resins are produced from coal-tar by-products. These neutral resins range in color from light to dark amber and vary in hardness from liquids to solids of high melting points, with excellent acid and alkali resistance. Cumars are soluble in nearly all solvents except alcohols and are miscible with most drying oils. They make particularly good aluminum vehicles because of their extremely low acidity.

The *maleics* are a series of light-colored, rosin-modified maleic anhydride resins, medium in acid value and soluble in most solvents. These resins have much less tendency to yellow than the phenolics. Maleics are used to a large extent in lacquers, being quite compatible with nitrocellulose and showing good solvent release which produces hard, fast-drying films. They are also widely used as varnish resins and as modifying agents in alkyd resins to improve the hardness and speed of drying.

Petroleum resins are now finding many uses in the coating industry. Some of these resins have the disadvantage of dark color, but they have been improved in this direction. Because of low acidity, petroleum resins are particularly good for aluminum vehicles and large quantities are used for this purpose. Both the oxidizing and non-oxidizing types are produced. The non-oxidizing types dry by the simple evaporation of solvent and leave a hard, dark film, with good alkali and acid resistance. The oxidizing types dry by evaporation and oxidation, either by exposure to the air, or by baking.

The *ureas* are water-white urea-formaldehyde resins; they usually dry through polymerization at elevated temperatures, although they can be

made to air-dry if suitable catalysts are employed. These resins are neutral and soluble only in alcohols. When modified with short-oil alkyds, ureas are used to advantage in the manufacture of enamels for refrigerator finishes.

Melamines have properties which are similar to those of urea resins, although they cure at lower temperatures and in shorter periods of time, consequently with less yellowing than may be encountered with the ureas that are baked at higher temperatures. Melamines are somewhat more chemical resistant than the ureas.

Acrylic ester resins are water white in color and soluble in hydrocarbons and esters. The dried films show little discoloration at high temperatures and are resistant to alcohol, water, alkali, acids, grease, and many chemicals, although they are attacked by certain solvents. These resins may be air-dried or baked, but the baked films are somewhat softer than those made from ureas.

The *vinyls* are a series of water-white resins, made with varying degrees of solubility. Most of them are soluble in ketones, though special grades that are soluble in other solvents are available. The vinyls are neutral and non-inflammable, resistant to moisture, alkali, acids, and oils. Cast films of these resins dry by evaporation at room temperature, or they may be baked, when suitably stabilized. The vinyl resins are used in artificial leather finishes, metal finishes, linings for tin containers, textile finishes, and for other requirements which demand extreme chemical or water resistance.

Styrenes and polystyrenes are clear, water-white resins, soluble in hydrocarbons; they vary from liquids to high-melting-point solids. They are soluble in most solvents and, therefore, cannot be used for solvent-resistant finishes. The styrene resins are thermoplastic neutral compounds which resist both acid and alkali and are used in varnishes and clear coatings or for modifying other finishes.

Rubber resins are rubber compounds modified with chemicals, such as chlorine or maleic anhydride, and are soluble in aromatic solvents but are usually insoluble in petroleum hydrocarbons and alcohols. Rubber resins are useful in floor paints and industrial enamels where chemical resistance, hardness, and fast-drying properties are important.

The resins discussed in this section are those which are most widely used; however, the list is far from complete. Many of the newer synthetics, such as the copolymers developed in the synthetic rubber field, are in the process of being accepted by the protective-coating industry, and many more are in the development stage.

Solvents. *Petroleum* (aliphatic) and *coal-tar* (aromatic) hydrocar-

bons are the most extensively used solvents in the paint industry. Lacquer formulators employ these products as diluents for other solvents which are described in the section under lacquers. The choice of hydrocarbon solvents is determined by the ability of the solvent to dissolve the resins and oils, by the rate of evaporation, and by flash point and toxicity. Petroleum hydrocarbons may vary greatly in distillation range and may be selected in accordance with the effects desired. Mineral spirits with a distillation range of 300 to 400°F is the most satisfactory solvent for paint formulation. V. M. & P. naphtha, which has a slightly lower distillation range and faster evaporation rate, and kerosene, which has a higher boiling point and evaporates more slowly, are also used in the industry. Aliphatic petroleum solvents when compared with the solvent power of the aromatics have relatively low solvency. Low-solvency petroleum thinners cannot be used with some resins and varnishes which are hard to dissolve, and it then becomes necessary to use aromatic hydrocarbons. The petroleum aliphatic hydrocarbons are not so toxic as the aromatics and are available in greater quantities at lower prices.

The aromatic hydrocarbons include those which are derived from both coal-tar and petroleum. The most commonly used are toluol, xylol, and high flash naphtha. The aromatics may be obtained in about the same distillation and evaporating ranges as the petroleum solvents and, in the same percentages, will reduce the viscosity of any coating more rapidly than the corresponding petroleum solvent.

In general it should be kept in mind that, in the selection of any hydrocarbon, the lowest-priced thinner which serves the purpose is most desirable. The solvent plays little or no part in the durability and general appearance of the film and, therefore, requires consideration of only physical properties essential to package stability and method of application.

Terpenes are another group of solvents used in the industry that includes turpentine, dipentene, and pine oil. They possess intermediate solvency, midway between the petroleum and aromatic hydrocarbons. Turpentine is one of the oldest solvents known to the industry, but has been replaced in many products by the less expensive hydrocarbons.

Vehicles. The vehicle, or liquid part of a paint and enamel coating, may be composed of oils, varnishes, and synthetic resins or complex mixtures of these materials. A solvent, known as the volatile portion, is usually present; the remainder of the vehicle is referred to as nonvolatile or solids. With the correct combination of drying oils, and the proper resins, either processed or synthetic, a wide variety of vehicles

can be made to meet practically every requirement for hardness, durability, speed of dry, color, cost, reactivity, chemical resistance, and other properties.

Pigmented Products

House Paints. Probably the best-known protective and decorative coating is *house paint,* since practically everyone has either used it or has seen it being applied by painters. A thorough understanding of the principles governing the composition of house paints will serve as an excellent basis for the study of all types of coatings.

House paints are generally composed of a vehicle, containing a high percentage of oil, to which has been added opaque pigments in combination with transparent or inert pigments. Since paints are designed to protect and decorate the surface over which they are applied, they should be resistant to weathering, sunshine, wear, moisture, and other conditions that cause the film to deteriorate. It is possible to control most of these factors by proper formulation.

The pigments and vehicle should be present in definite proportions. Their ratio is commonly known as the PVC or pigment volume concentration, which is the per cent by volume of the pigments in the nonvolatile portion of the paint. This may vary from 27 to 38 per cent, depending on the oil content of the vehicle and the type of pigments being used. The percentage of each type of pigment in the formula is also very important in maintaining a good product. Most house-paint formulas reflect the results of years of testing by paint manufacturers and raw-material suppliers.

Pigments. Except possibly in interior paints and enamels, no one hiding pigment alone will give the best results; and one or more inerts are usually necessary to provide good durability. In fact, the selection of pigments is often a compromise with respect to inherent properties which will produce a firm film that is not too hard or a chalking film that chalks at the proper rate to maintain good appearance. The opaque pigments generally employed in white house paints are white lead carbonate or sulfate, zinc oxide, titanium dioxide, and lithopone. The pigment that is frequently used by itself is lead carbonate, commonly known as white lead. Combinations of opaque and inert pigments are customary to obtain the optimum results for exterior exposure.

That single-pigment paints do not offer the best overall qualities for outside use is well established. This also applies to colored house paints, although a few colors, such as the red iron oxide paints, do not present the same problem as whites and certain other shades. At one time it

was assumed that inerts, such as asbestine, mica, (talc,) barytes, and silica were used only as adulterants, but durability tests have shown that, when properly formulated, inerts actually increase the life of the paint.

Some inerts are added to or coprecipitated with the hiding pigments during the process of manufacture, as is true with titanium dioxide-calcium sulfate pigment and zinc sulfide-barium sulfate pigment, the latter commonly known as lithopone. These pigments are mixtures that are somewhat superior in quality to the same materials added separately. Generally speaking, the pigment portion in outside paints is a two-phase system of hiding pigments for opacity and inert or transparent pigments for reinforcement. The inert portion may contribute many properties, such as controlled weather resistance, body, ease of application, appearance, adhesion, and lower cost. The primary purpose of the hiding pigment is to obscure the surface when applied, but its secondary objective is durability. The experience of most formulators enables them to choose a satisfactory combination of pigments of both types for maximum durability and best appearance throughout the life of the paint.

Vehicle. The vehicle portion of house paints may be composed of an oil (generally linseed) or a combination of oils, plus a solvent, such as mineral spirits or turpentine, and finally a small amount of drier. The vehicle must be so designed that, when the pigment portion is added, the finished paint will possess the characteristics desired to control body, flow, brushing, hardness, gloss, elasticity, and adhesion. Bodied linseed oil (refined oil heated to obtain a heavy viscosity with low acid number) is generally added to raw linseed oil in amounts up to 50 per cent to provide better gloss, flow, and durability. If insufficient bodied oil is added, the flow, or smoothness of the brushed-out film, will be impaired; but, on the other hand, an excess of bodied oil will add "pull" to the paint and make application with a brush difficult. The so-called body or consistency of a paint can be controlled to some degree by adding high- or low-oil-absorption pigments that increase or decrease the viscosity without disturbing the composition. At the same time, the chemical activity of both the vehicle and the pigments may be responsible for variations in body, and reactive pigments, such as zinc oxide and white lead, should be used with relatively neutral vehicles. High-acid varnishes or bodied oils should not be employed with reactive pigments, but careful selection is not so important with inactive types, such as titanium dioxide, lithopone, and with some colors. With the increased popularity of linseed-oil substitutes, essentially in the form of special varnishes, other problems have developed. Some of these varnishes contain considerable resin and have a tendency to increase the hardness and gloss of paint films beyond established acceptance. Generally, the durability of most coat-

ings can be determined only after exhaustive long-term exposure tests, and care must be exercised before new formulations are accepted.

In addition to the exterior paints containing the white pigments mentioned above, a class of exterior paints known as fumeproof products is in some demand. This term indicates that there is no lead or other pigments present in the formulation which tend to darken in the presence of sulfur fumes. Providing they are perfectly formulated, such paints have application and durability characteristics similar to ordinary types. Fume-resistant paints are recommended for areas where normal white or light-colored paints would darken, owing to chemical fumes in the atmosphere.

Enamels. The *enamels* account for a large proportion of the total output of the paint industry. The distinguishing characteristics of enamels as compared to oil paints are higher gloss and harder and more rapid drying. Gloss enamels, which have relatively low pigment content, are finely dispersed by grinding dry colors into vehicles containing varnishes and sometimes oils.

Small amounts of pigments are used in order to obtain the best possible gloss, and it is, therefore, necessary to use high-hiding pigments and the minimum of inerts. All pigments must be finely ground, since any coarse particles decrease the gloss and cause a seedy appearance in the finished film. Pigments that are most easily dispersed and provide the qualities required of the enamel are selected. For exterior enamels, pigments of good durability are desirable; for interior, non-yellowing whites, those which are unaffected by fumes are required. Quite often price is a factor, and it then becomes necessary to employ a pigment that may not be the best in all respects but which will do a satisfactory job.

The vehicles contained in enamels are composed of varnishes, oils, and driers. The individual characteristics desired in the finished enamel determine the most appropriate liquids to use. For white enamels, only the lightest-colored vehicles are selected so that the least possible discoloration of the white pigment is caused by the vehicle. Color retention is also a factor, and, therefore, the non-yellowing qualities of the vehicle on ageing are equally important for maintaining a satisfactory appearance after the enamel is applied. In tints and darker-colored enamels, the original color of the vehicle is not so exacting.

The durability of the vehicle is of prime importance, especially for exterior enamels, which are usually high in oil content. This vehicle may be in the form of a long-oil flexible varnish or a combination of varnishes and oils. It may also consist of a very durable resin solution that contains little oil but is treated in such a way as to perform well on exterior exposure. Alkyd varnishes are typical of satisfactory vehicles

for these conditions. Durability is not so important for interior enamels, but attention is directed to gloss retention and resistance to washing, kitchen fumes, and wear. Along with the above qualities, speed of dry, adhesion, and many of the other properties desired in a good enamel must be attained.

For the air-drying, brushing type of enamels which are sold to painters and householders, it is necessary to include easy brushing, non-sagging, good odor, and consistency that is neither too thin nor too heavy for proper application.

The enamels, known to the trade as industrial enamels, for covering manufactured products, are divided into air-drying and baking types. The air-drying products are composed of pigments and vehicles similar to those for brushing air-dry enamels, although they are modified to meet particular requirements for dipping or spray application, drying time, and film properties.

The baking-type industrial enamels cover a very extensive field. They include ordinary oleoresinous enamels which are modified by drier changes in order to bake or force-dry properly on a given schedule and also the modern synthetic products which bake to produce hard, mar-proof, porcelain-like finishes, such as are found on refrigerators, stoves, and some automobiles. These synthetic finishes contain heat-hardening urea, melamine, and modified alkyd resins which produce an exceptionally hard finish. Some baking enamels employ phenolic, vinyl, acrylic, and rubber resins and gilsonite black to protect surfaces in contact with corrosive acids, alkalies, and other chemicals. The manufacture of suitable finishing materials to meet the production and baking schedules of other manufacturers requires skill and care on the part of the laboratory as well as the production personnel. Proper formulation, careful manufacturing, and intelligent testing must work hand in hand to obtain products that merit the confidence and demands of the industrial consumer.

Flats. Flat paints are usually interior finishes made with the minimum of gloss or low angular sheen. *Flats* show no gloss when viewed directly near the surface but may be formulated in varying degrees of gloss when they are inspected at an angle of 60° or less. They should be capable of easy application, and the dried film should have some washability, as well as good hiding properties. Flat paints are primarily used on the interior walls of dwellings and office buildings.

Proper formulation of flats requires the correct balance of pigment and vehicle, as well as the proper types of each. A non-glossy surface should be as uniform as possible, free from "flashing" with no high- and low-gloss spots in the dry film. Also no light and dark areas should be visible when tinted flats are applied to large surfaces. In the formula-

tion of flat wall paints, vehicles are chosen for easy brushing and controlled penetration characteristics. Pigments selected are those which will give the most economical results in regard to hiding, application, and film properties. Titanium dioxide, titanium-calcium pigments, and lithopone are examples of the hiding pigments. Whiting or calcium carbonate, asbestine, silica, and diatomaceous earth pigments are the most commonly accepted inerts.

These materials, many of which can be treated in various ways during the manufacturing process to control consistency, flow, and penetration, provide a fairly wide range of selection. Titanium-calcium pigment may be the prime pigment with some pure titanium dioxide added to improve the dry-film hiding. The inert or flatting pigments may consist of one or more of those mentioned in the preceding paragraph.

The vehicle, usually called flat wall vehicle, may consist of raw and treated oils, varnishes with flatting properties, and combinations of these liquids. Slow-evaporating solvents, mineral spirits and kerosene, are generally employed, in order that the paints can be brushed on large surfaces without showing overlaps, i.e., they should retain a "wet edge" at the point of contact between the fresh and the partially set film while the paint is being applied.

The vehicle solids must be held at a predetermined level to obtain proper consistency, flow, and dry-film hiding, in the range of 25 to 35 per cent. Bodied oils and varnishes are used to control penetration, leveling, vehicle solids, and brushing characteristics. The amount of vehicle solids required depends on the film characteristics desired and varies with the pigment composition. In general, an increase in the solids of the vehicle adds gloss to the paint because of the proportionate decrease in the ratio of dry pigment to the film-forming solids.

Ordinarily, flat paints contain a much higher percentage of pigment, combined with lower vehicle solids, than gloss paints or enamels. Satisfactory flats are just as difficult to formulate and manufacture as house paints and, in most cases, are the result of careful balancing of oils and varnishes with correct pigment combinations to produce acceptable products. The specific qualities obtained from one material may detract from the value of another, so that usually a compromise must be worked out to secure best results. Mixing and grinding generally do not present serious problems in the manufacture of flats, since they do not require the fine texture associated with enamels.

Semigloss paints or enamels represent a class of interior paints that are rather closely related to flats. As the name indicates, they dry with a higher luster than the flats; they range from eggshell sheen to a nearly

full gloss. Semigloss products fall between flats and enamels in pigment content and vehicle solids. They require finer grinding than flats and are generally applied where a hard washable surface is desired without the glare of gloss enamels. Semigloss finishes are very popular for household and building maintenance.

Trim Paints. Practically all houses are painted around the windows and doors with a contrasting colored paint known as *trim paint.* Products for this purpose have higher gloss, are harder, and contain colored pigments other than those used for regular house paints. Green, blue, black, and brown are popular, but many other colors are used to provide contrast in a pleasing color scheme. They should be highly resistant to fading and dirt collection, should brush well, and have good adhesion to the old paint surface.

The pigment portion of trim paints is confined to high-hiding pigments with good color retention. Solid-color pigments are preferred to those reduced with white opaque pigments, since the solid colors have less tendency to show fading on exposure to the weather. Sometimes inert pigments are combined with the pure colors to control body, working properties, and cost, but it is still desirable to maintain a relatively high color content for best results.

The vehicle in modern trim paint is ordinarily a varnish, preferably a durable, synthetic-resin type possessing good flexibility. Such vehicles vary from medium to heavy in viscosity, since the lower pigment content does not affect the body of the final product to the same degree as that of standard house paints. Bodied oils are often blended with these vehicles to regulate both viscosity and gloss.

Since trim paints are finely ground to give high gloss, the presence of hard-grinding inerts are objectionable from a production viewpoint; however, some of the colored hiding pigments themselves present difficult grinding problems.

Primers. Most house paints work best when they are applied over a *primer.* Unpainted wood always requires special treatment, and painted wood may also need special consideration, depending on the condition of the old surface. It has been the custom to apply three coats to unpainted wood, linseed oil and thinner being added to the paint in varying amounts with each coat. For the first coat a definite amount of penetration is required to give good adhesion, but the amount should not be so great that very little paint remains on the surface. With a vehicle of the proper viscosity and a correct combination of oils, controlled penetration into the wood can be obtained. The second coat is applied with only slight reduction, since opacity and adhesion to the first coat are

important. The final coat is applied evenly and with little or no reduction over the properly prepared undercoats. At least an overnight drying period should be allowed between coats.

Many paint men now believe that a properly formulated two-coat system may be employed for new or old work. Instead of simply reducing the paint for successive coats, this method requires a special primer containing treated oils and long-oil varnishes which must be formulated separately. Experience seems to offer some justification for the procedure, since the functions of the two coats are entirely different: the primer acts as a filler with good adhesion and hold-out properties; the topcoat provides durability and good appearance. The primer or undercoat is designed to prevent uneven penetration into the wood and premature breakdown of the film. Balanced pigmentation is obtained with both opaque and inert pigments, which may or may not be of the same type as the top coat. Special primers made with powdered aluminum as the pigment are entirely satisfactory when they are properly formulated. In some instances, two coats of paint over the aluminum may be required to secure perfect hiding of light tints.

Enamel undercoats for wood are used in preparing interior surfaces for the application of finishing coats. These undercoaters consist of hiding and inert pigments combined with a vehicle to produce a hard-drying product which can be sanded lightly to present a smooth even surface for succeeding coats. The sheen of enamel undercoaters is usually eggshell or a very low semigloss so that the surface will not be too smooth and glossy for proper adhesion of the finishing coats, nor too rough and flat for good appearance and "hold-out" of succeeding coats. Enamel undercoaters are not to be confused with ordinary flat white paints, since they are usually ground finer and are formulated to produce tight, hard-drying surfaces for the application of finishing enamels. Flat white paints such as those applied to walls are usually more coarsely ground, are more porous, and contain less vehicle solids than enamel undercoaters.

Another type of primer for wood is the *primer-surfacer*. This is designed for application on open-grained or rough-surfaced lumber. To ensure a smooth surface for the finishing enamel, a heavy coat is applied that dries firm and hard to facilitate sanding. Primer-surfacers are more highly pigmented than enamel undercoaters and, as they generally dry somewhat harder, are more easily sanded. Primer-surfacers are useful not only under paints or enamels but also under lacquers when they are formulated so that the strong lacquer solvents will not lift or remove them.

Both the above products can be made from a wide variety of alkyd

or oleoresinous varnishes blended with oils and can be pigmented to practically any desired color.

Metal primers are divided into two general classes. The first type is for application on rough metal such as castings. They are highly pigmented, hard-drying sealers, which can be sanded easily to present a smooth, hard, non-porous surface for the finishing coats, and are usually based on alkyd or oleoresinous vehicles and pigmented to whatever color is required. In a lacquer system, these products must resist the lifting effect of strong solvents.

The other class of metal primers is used as a corrosion-resistant coat between the metal and the finishing coats. Maximum adhesion and a satisfactory surface for additional coats are essential requirements for the primer on metal surfaces. First coaters for metal can be made from all sorts of vehicles, depending on the conditions to which they are subjected, and the applied films may vary from dull to high gloss when they are dry. Many metal primers, such as those used for marine work, are designed for inhibiting rust on iron or steel surfaces and are pigmented with various lead and zinc compounds, with or without other pigments. Some primers, to afford primary protection for iron, steel, aluminum, magnesium, and many alloys, may be designed as a part of a finishing system to resist chemicals. Advance knowledge of the surface to which a primer will be applied is very important, since it will determine to a large extent the best combination of pigments and vehicles to be recommended.

The vehicle composition of primers is indeed flexible. They can be made from ordinary oils and resins, varnishes, alkyds, vinyls, and other film-forming materials. The proper selection depends on the specifications for durability, water resistance, blistering, and tests of a specific nature.

The selection of pigments to meet the requirements is equally important. With respect to the hiding pigments, primers ordinarily contain a relatively high percentage of inert pigments, and the pigment-inert characteristics must be considered carefully. As an example, barytes and calcium carbonate are dense, heavy pigments that promote hard, tight films; mica contributes adhesion; silica and the silicates contribute a porous structure and breathing characteristics to the film that can beneficially affect the sanding properies of primers. Diatomaceous earth is effective in the control of the water permeability and gloss of primers. Many other inert pigments, both treated and untreated, have special properties that may be used to advantage in primer formulation.

Primers also requre special attention to the pigment-vehicle solids ratio since this relationship has a pronounced bearing on their performance.

Excess pigment can make a film brittle and cause it to adhere poorly. A high percentage of vehicle solids usually causes slower drying, more sheen, and overshadows the desirable characteristics of the individual pigments. Pigment-vehicle ratios in primers vary from 25 to 40 per cent with the primer surfacers running higher than these figures.

The fineness of grind for a primer should be standardized and adhered to closely by the manufacturing department. A loose grind presents a rough surface for succeeding coats that is often porous, whereas over-grinding affects the sheen and permeability of the primer and may cause noticeably slower drying. Primers are a highly important component of any finishing system and require just as much care in production as enamels or any other coating.

Wall primers are specially prepared coatings for the purpose of sealing porous wall surfaces which may be either new plaster or plaster previously painted. Ordinarily, these products have a low pigment content with high hiding characteristics in combination with a vehicle that possesses properties for adhesion and maximum "hold-out" of succeeding coats, so that a uniform finish will be obtained when flats and semi-glosses are applied, particularly in color. The practice of applying properly designed wall primers is good insurance against serious complaints, often attributed to the finishing coats of paint and enamel.

In general, all primers may be employed as undercoaters for enamels or as bonding coats between the surface and the finish, but they may not inhibit corrosion of metallic surfaces, unless they are designed for this purpose. Primers are pigmented with both hiding and inert pigments, a great deal of emphasis being placed on the type of inert in order to obtain the properties desired. The priming coat should prevent uneven absorption of the top coats but at the same time allow enough penetration to obtain good adhesion.

Varnishes

Varnish is generally understood to mean processed resins and oils, reduced with solvents, to which metallic driers or catalysts have been added. The production of varnish involves heating the oils and resins in kettles at various temperatures. Certain types of varnishes are mechanically mixed or cold cut. Cold-cut varnishes are mixtures of resins and solvents, agitated and dissolved without heating, and are usually identified by the name of the resin. Shellac, ester gum, and limed-rosin (gloss oil) solutions are examples.

The oils used in varnish include china wood oil (tung), treated linseed, soybean, dehydrated castor, oiticica, fish, and many others, alone or in combination, each producing different results. Tung oil is often

regarded as the best all-around varnish oil, but many specially treated oils, derived from linseed, castor, oiticica, and soybean, have been developed as satisfactory substitutes. Some of these substitutions have improved the flow, reduced the skinning tendencies, and eliminated the wrinkling and frosting inherent in tung oil.

The solvent may be a regular aliphatic petroleum solvent, having relatively low solvency, or it may be an aromatic solvent derived from coal tar or petroleum, for use with less soluble varnishes, such as short-oil alkyds or phenolics. The driers are usually metallic compounds of lead, manganese, and cobalt.

The elasticity of regular oil varnish is described by stating the number of gallons of oil per hundred pounds of resin contained in the varnish and is referred to as oil length. In general, long-oil length indicates a tough, flexible varnish that is very durable, such as an exterior spar varnish. Conversely, varnishes that are low in oil length, termed short-oil, dry harder and faster, and have less flexibility than long-oil products; they are more suitable for finishing furniture. Medium-oil-length products are employed for floor, trim, and other interior surfaces that require a tough, wear-resistant finish.

The classification of varnish containing less than 12½ gal of oil per hundred pounds of resin as short, between 12½ and 25 gal as medium, and over 25 gal as long-oil is generally accepted. Alkyd varnishes are not described in this manner but are defined by the percentage of phthalic anhydride calculated on the non-volatile. If the percentage of phthalic anhydride is 30 or over, it is a short alkyd and is the baking type. Low phthalic content, below 30 per cent, is usually associated with grinding vehicles for architectural enamels.

The non-volatile content by weight of varnish products usually varies from 45 to 55 per cent, depending on the purpose for which these products are designed, the results desired for gloss, working properties, and drying time, and whether they are to be pigmented or used as clear coatings.

Baking Varnishes. Although many air-drying varnishes may be force-dried and the drying time may be considerably reduced by this process, there is a separate class of products that can only be hardened by baking at elevated temperatures. These vehicles dry by evaporation, polymerization, and, to a lesser extent, by oxidation. Urea and melamine resins, along with the short-oil alkyds, plus combinations of these resins, are commonly used for baked finishes. A good urea-alkyd combination, when ground with a white pigment, such as titanium dioxide, produces a hard, porcelain-like finish, required for washing machines and refrigerators. Baking schedules for these products may vary from 3 sec at

500°F (flash bake) to 30 min at 300°F, which is the more normal practice. Other baking varnishes, used on wooden handles, lithographed tin, electrical insulation, and automobile bodies, are baked from 30 min at 300°F to 8 hr at 140°F. Metal finishes may be cured either with infrared heat or in convection ovens, which employ gas or electricity as the source of heat. Infrared heat has been found quite satisfactory also for the baking of wood finishes, although it is not so effective as for metal coatings.

Flat Varnishes. Flat, or eggshell, varnish is the term applied to the clear or translucent products that dry between a dull flat and a high semigloss sheen. These finishes are based on medium- and short-oil varnishes, pigmented with small amounts of low-opacity, finely ground inerts, such as aluminum and zinc stearates or palmitates, and siliceous pigments. Dull and semiluster varnishes provide an economical method of reproducing the hand-rubbed and polished effect which many consumers prefer for furniture and woodwork.

Lacquers

At the present time the accepted use of the term *lacquer* is confined to finishes containing nitrocellulose, although it may also be applied to finishes containing other cellulose derivatives, such as cellulose acetate and ethyl cellulose. Lacquers differ from most other coatings since the film dries entirely by evaporation. The presence of nitrocellulose, which is insoluble in petroleum and aromatic solvents, requires a careful balance of blended solvents and diluents in order to form solutions that are useful as coating materials. Therefore, in addition to the usual considerations pertaining to pigment and vehicle solids, the formulation of lacquers involves detailed study of many types of solvents, particularly the ordinary ketones, esters, alcohols, and hydrocarbons.

Lacquers also contain an ingredient known as plasticizer, which influences the film characteristics. Plasticizers fulfill some of the functions attributed to drying oils in varnishes with respect to flexibility and the promoting of adhesion of lacquer films. Non-drying vegetable oils, such as castor, along with organic esters, such as dibutyl phthalate, are typical examples of softeners and plasticizers in general use. One of the most important requirements of the plasticizers is compatibility with the resins. The resins employed in the manufacture of lacquers must also be compatible with the remainder of the film-forming solids, in order to avoid cloudiness and a weak film structure in the dry film. The selection of the resin will depend on the type of lacquer desired and whether it will be used as a clear or pigmented finish.

Both clear and pigmented lacquers are produced in considerable quan-

tities for the industrial trade where hard, durable, fast-drying finishes are necessary. Lacquer coatings are manufactured in closed equipment, such as dough mixers and ball or pebble mills, to prevent expensive solvent losses and also as a safety measure. Pigments dispersed in nitrocellulose and plasticizers are then added to or reduced with resin-solvent mixtures in closed mixing tanks. This operation is somewhat similar to the addition of colored pastes in oil or varnish, when such pastes are added to paints as a tinting material. Fast-evaporating solvents make it impracticable to manufacture pigmented lacquers in the customary manner, since the removal of solvents quickly deposits a dry solid film on the grinding surface of open equipment such as roller mills.

Owing to the inherent viscosity of nitrocellulose and cellulose acetate, clear lacquers have a very low solid content, approximately 20 per cent, compared with 50 per cent for the average varnish. The flexibility, toughness, adhesion, and other properties of lacquer films can be regulated by changing the amount and type of resin and plasticizer, as well as the type of cellulose, employed. Pigmented lacquers are among the most durable outside coatings that have been developed; they have been in use for many years as one of the standard finishes for automobiles.

Lacquer Solvents. Since the solvents play such an important part in a lacquer coating, a working knowledge of their properties is essential. The active solvents, those which dissolve the nitrocellulose, such as the esters, ketones, cellosolves, and a few others, must be slower evaporators than the diluents, or non-solvents. Blends of the so-called active solvents are selected from the viewpoint of evaporation rate, solubility of the resin and of the nitrocellulose. A second group, known as latent solvents, usually alcohol, will not dissolve nitrocellulose, but, in the presence of active solvents, are effective. A third group, the diluents, which are hydrocarbons, include only the fast-evaporating types, such as toluol and the hexane-heptane mixtures. During the manufacture of lacquer, the diluents are added last, since they are non-solvents, and have limited tolerance for the resin and nitrocellulose solids. Nevertheless, they form a substantial portion of the finished lacquer and reduce the cost and improve the working properties required for application.

The evaporation rates of all three groups of liquids must be properly balanced, so that the active solvent evaporates from the film last of all, or, at least at the same rate as the non-solvents and diluents, in order that the film should remain clear. Simultaneously, the rate of evaporation for all solvents must be retarded under certain conditions to avoid the condensation of moisture and the clouding or "blushing" of the film.

Lacquer Resins. A satisfactory resin should be compatible with the cellulose and plasticizers, and at the same time soluble in alcohols, esters,

and hydrocarbons. In addition, the resin component is expected to be durable and tough and to increase the adhesion to surfaces on which the lacquer is applied. Ester gum and the natural resins, such as dammar and manila, have been used extensively in lacquers, but satisfactory replacements have been developed with synthetic resins.

Lacquer Pigments. Most of the common pigments may be used satisfactorily in lacquers, and the selection is largely dependent on color, hiding, durability, and reactivity. Many colors, particularly the organic reds, such as the toluidines, paras, and lithols, show a tendency to bleed, or dissolve, in certain lacquer solvents, thus eliminating these pigments for some uses. This "bleed" also becomes a factor when the production equipment is being cleaned, and extra caution must be exercised in changing from one color to another.

ACKNOWLEDGMENT

The preparation of this chapter by F. B. Robinson and the valuable assistance of L. F. Wagner, J. P. Harner, and J. P. Snyder on behalf of the Philadelphia Paint and Varnish Production Club are gratefully acknowledged by the editors.

REFERENCES

		Vol.	No.	Page	Month	Year
Aluminum Paints						
Review.	*Official Digest*		246	205	May	1945
Vehicles.	*Official Digest*		260	393	Sept.	1946
Recent Developments.	*Official Digest*		269	342	June	1947
Anti-Fouling Paints (also see Marine Paints)						
Anti-Fouling Paints.	*Official Digest*		258	309	July	1946
Anti-Fouling Paints.	*Ind. Eng. Chem.*	38		931		1946
Anti-Fouling Paints.	*Ind. Eng Chem.*	38		806		1946
Anti-Fouling Paints.	*Ind. Eng. Chem.*	38		612		1946
Anti-Fouling Paints.	*Ind. Eng. Chem.*	38		699		1946
Automobile Finishes						
Protective and Decorative Coatings.	Mattiello	III		430		
Asphalts and Bitumens						
Asphalt Paints.	Mattiello	III		232		
Asphalts and Allied Subjects.	Abrahams (Van Nostrand)	I & II				1945
Asphalt Roof Paint						
Asphalt Paints.	Abrahams (Van Nostrand)					
Asphalts and Allied Subjects.	Mattiello	I		751		
Applications						
Application on Wood.	Mattiello	III		294		
Behavior of House Paint on Different Woods.	F. L. Browne, Forest Prod. Lab. Series		62			
House Painting Methods.	F. N. Vanderwalker (Drake)					
Metal Surfaces—Preparation and Painting.	*Official Digest*		280	357	May	1948

REFERENCES *(Continued)*

		Vol.	No.	Page	Month	Year
Baked Finishes						
Baked Finishes.	*Official Digest*		251	527	Dec.	1945
Heat-Resistant Baked Finishes.	*Official Digest*		231	482	Dec.	1943
Baking Enamels—Infrared.	*Official Digest*		251	537	Dec.	1945
Baking Varnishes—Infrared.	*Amer. Paint J.*	30	6B	29		
Baking Finishes—Infrared.	*Am. Paint J.*	30	6B	16		
Baking Finishes—Infrared.	*Ind. Finishing*	21	6	37		
Colors						
Pigments—White and Colored.	Mattiello	II				
Spectral Characteristics, Pigments.	Mattiello	V		345		
Color.	Mattiello	IV		95		
Physical & Chemical Examination of Paints, Varnishes and Lacquers.	Gardner			66		1946
Consistency						
Consistency.	Mattiello	III		367		
Consistency.	Gardner			299		1946
Concrete and Stucco Paint						
Concrete and Stucco Paint.	Mattiello	III		309		
Driers						
Driers in Paints and Enamels.	Mattiello	III		206, 279, 350		
		I		499		
Report of Montreal Club.	*Official Digest*		220	489	Nov.	1942
Loss of Drying.	*Official Digest*		221	546	Dec.	1942
Effect on Varnish Films.	*Official Digest*		270	421	July	1947
Emulsion Paints						
Alkyd Emulsion Paints.	Mattiello	III		488		
Protein Water Paints.	Mattiello	III		482		
Casein Paints.	Mattiello	III		461		
Emulsion Paints.	*Official Digest*		247	300	June	1945
Emulsion Paints.	*Official Digest*		302	212	March	1950
Vinylites.	*Official Digest*		276	114	Jan.	1948
Interior Emulsion Paints.	*Official Digest*		243	69	Feb.	1945
Enamels						
Air Dry Auto Enamels.	Mattiello	III		445		
Enamels.	Mattiello	III		378		
Paints and Interior Enamels.	Mattiello	III		333		
Fire-Retardent Paints						
Fire-Retardent Paints.	*Official Digest*		262	575	Nov.	1946
Flameproofing Textiles.	Little, *ACS Monograph*			104	(Reinhold)	1947
Floor Paints						
Floor-Paint Vehicles.	*Official Digest*		263	669	Dec.	1946
Floor-Paint Vehicles.	*Official Digest*		276	77	Jan.	1948
Flat Paints						
Properties.	Mattiello	III		367		
Effect of Pigments.	*Official Digest*		269	321	June	1947

REFERENCES (*Continued*)

		Vol.	No.	Page	Month	Year
Flat Paints (*Continued*)						
Pigmentation of Interior Finishes.	*Official Digest*		247	308	June	1945
Formulation						
Paint and Film Properties.	Mattiello	III		352		
Gloss Paints						
Gloss Paints.	Mattiello	III		378		
Control of Gloss.	Mattiello	III		381		
Measurement of Gloss.	*Official Digest*		266	153	March	1947
Study of Gloss Measurements.	*Official Digest*		250	447	Nov.	1945
Grinding						
Mixing and Grinding Equipment.	Mattiello	III		727		
Measurement of Fineness.	*Official Digest*		263	633	Dec.	1946
Hiding						
Hiding of Interior Paints.	Mattiello	III		363		
Hiding Power.	Gardner			9		1946
Measurement of Hiding.	*Official Digest*		231	485	Dec.	1943
Hiding-Power Review.	*Official Digest*		253	64	Feb.	1946
House Paints						
House Paints.	Mattiello	III		269		
Postwar Exterior House Paints.	*Official Digest*		244	123	March	1945
			266	139	March	1947
Function of Reactive Pigments.	*Official Digest*		253	83	Feb.	1946
Pigment-Volume Concentration.	*Official Digest*		276	138	Jan.	1948
Four-Year Test Program.	*Official Digest*		278	279	March	1948
Interior Finishes						
Paints and Enamels.	Mattiello	III		333		
Pigmentation of Interior Finishes.	*Official Digest*		247	308	June	1945
Titanium Dioxide Pigmentation.	*Official Digest*		253	72	Feb.	1946
Lacquer						
Nitrocellulose Lacquer.	Mattiello	III		497		
Lacquer Solvents.	Mattiello	III		510		
Solvent Release.	*Official Digest*		276	3	Jan.	1948
Hot Spray Application.	*Official Digest*		309	721	Oct.	1950
Linoleum						
Resilient Floor Coverings.	*Official Digest*		301	105	Feb.	1950
Marine Finishes (see also Anti-Fouling Paints)						
Marine Paints.	Mattiello	III		386		
Fouling Organisms.	Mattiello	III		401		
Ship-Bottom Paints.	*Official Digest*		222	14	Jan.	1943
Microscopy						
In the Paint Industry.	*Official Digest*		247	288	June	1945

REFERENCES (*Continued*)

		Vol.	No.	Page	Month	Year
Metal Coatings						
Metal Coatings.	Mattiello	III		310		
Automotive Metal Coatings.	Mattiello	III		430		
Adhesion of Lacquer.	*Official Digest*		221	59	Dec.	1942
Paints as Moisture Barriers.	*Official Digest*		267	197	Apr.	1947
Formulation of Zinc Yellow Primers.	*Official Digest*		256	196	May	1946
Painting of Steel Ships.	*Official Digest*		261	443	Oct.	1946
Formulation of Industrial Finishes.	*Official Digest*		305	418	June	1950
Industrial Finishes and Finishing.	*Official Digest*		280	383	May	1948
Oils						
Drying Oils.	Mattiello	I		57		
Newer Varnish Oils.	*Official Digest*		246	240	May	1945
Raw and Processed Drying Oils.	*Official Digest*		290	115	March	1949
Paints (see also House Paints, Flats)						
Exterior Finishes.	Mattiello	III		269		
Exterior Trim Paints.	Mattiello	III		315		
Railroad Coatings.	Mattiello	III		410		
Farmers' Paint Bulletin.	North Dakota Agricultural College					
Pigmentation in Paints.	*Ind. Eng. Chem.*	26		956		1934
Pigmentation in Paints.	*Ind. Eng. Chem.*	26		1245		1934
Pigmentation in Paints.	*Ind. Eng. Chem.*	18		1220		1926
Pigment Volume Ratio.	*Official Digest*		276	138	Jan.	1948
Pigment Volume Ratio.	*Ind. Eng. Chem.*	27		905		1935
		29		1018		1937
		32		232		1940
Plasticizers						
Plasticizers in Lacquer.	Mattiello	III		525		
New Developments.	*Official Digest*		255	172	Apr.	1946
Vinylites.	Bakelite Corporation (booklet)					
Plasticizers.	*Plastics Encyclopedia*					
Primers (see also Metal Coatings)						
Marine Primers.	*Official Digest*		267	229	Apr.	1947
Metal Primers.	*Official Digest*		234	115	March	1944
Surface Preparation.	*Official Digest*		234	115	March	1944
Industrial Primer-Surfacers.	*Official Digest*		273	572	Oct.	1947
For Ferrous Metals.	*Official Digest*		275	745	Dec.	1947
Wood Primers.	*Official Digest*		265	88	Feb.	1947
Wood Primers.	*Ind. Eng. Chem.*	22		855		1930
		27		292		1935
		28		403		1936
Sealers (See also Primers, Metal)						
Evaluation of Finishes.	*Official Digest*		276	64	Jan.	1948

REFERENCES (*Continued*)

		Vol.	No.	Page	Month	Year
Semigloss Finishes						
Effect of Pigment.	*Official Digest*		269	321	June	1947
Semigloss Paints.	Mattiello	III		378		
Solvents (See also Lacquer)						
Thinners-Solvents.	Mattiello	I		537–641		
Application in Paint Industry.	*Official Digest*		293	326	June	1949
New Developments in Solvents.	*Official Digest*		255	172	Apr.	1946
Petroleum Solvents.	*Official Digest*		309	683	Oct.	1950
Stains						
Formulation and Use of Stains.	Mattiello	III		769		
Organic Finishes.	Wampler (Chem. Pub. Co.)			35		
Testing						
Plant Control.	*Official Digest*		263	663	Dec.	1946
Methods of Laboratory Test.	*Official Digest*		276	96	Jan.	1948
Methods of Test.	*Ind. Eng. Chem.*	28		934		1936
Methods of Test.	*Ind. Eng. Chem.*	35		161		1943
Varnish						
Oleoresinous Varnish.	Mattiello	III		29–268		
Vehicles						
House-Paint Vehicles.	Mattiello	III		278		
Trim-Paint Vehicles.	Mattiello	III		323		
Interior Paint Vehicles.	Mattiello	III		346		
Floor-Paint Vehicles.	*Official Digest*		263	669	Dec.	1946
Weathering						
Laboratory Test of Metal Finishes.	Mattiello	V		247		
Water Resistance.	Mattiello	IV		194		
Exposure Tests.	Mattiello	III		288		
Weathering Machine Correlation.	*Official Digest*		276	44	Jan.	1948
Eval. Finishes for Fir	*Official Digest*		276	64	Jan.	1948
Wrinkle Finishes						
Wrinkle Finishes.	Mattiello	III		250		
Wood						
Behavior of House Paints on Different Woods.	Mattiello	*Protective Coatings*, Special Military Edition, p. 258				
Behavior of House Paints.	Forest Prod. Lab. Series					

CHAPTER 5

ENGINEERING

The high quality which has been attained in the manufacture of paint products is due to the remarkable advances in paint chemistry and paint engineering. There was a period when it was difficult to duplicate laboratory precision in the plant. Now, however, with modern equipment and the application of sound engineering principles it is unusual for production batches not to match standards that have been established by the laboratory. Proper control of each raw material which enters the plant and complete supervision of every step in manufacturing are the prerequisites for the economical production of uniform and acceptable products.

Inventory

Raw-Material Estimating. The purchasing of raw materials can be practically automatic if a definite routine is established. The overall estimate for material control is largely dependent on the knowledge of the type of products manufactured. In an established business, the sales of various products are rather well defined and an accurate forecast is possible for the quantities required for the production department during any period.

Raw materials which are consumed regularly in large volume should be bought on contract for as long a term as is consistent with requirements and market conditions. This will afford protection for the manufacturer against price increases and will give the raw-material supplier a working schedule so that commitments can be fulfilled on time. In order to work out a satisfactory schedule for the delivery of raw materials, the production figures can be projected on a monthly basis for all the products to be processed during the month. The quantities and flow of incoming stock required can then be regulated from this production sheet. The proper timing of the delivery of raw materials is important, as well as the simultaneous arrival of cans, labels, and cartons of the proper size in which to package and ship the products when they are finished.

It is advisable for the purchasing agent and the head of the develop-

ment laboratory to contact each other in order to check on formula changes that will affect existing contracts or that may introduce additional problems concerned with the purchase of new items. By close cooperation between the purchasing and operating departments, the obsolete raw-material list which is a problem with all companies can be reduced to the minimum.

Inventory Control. A perpetual inventory system for the purpose of control is conveniently maintained from production records. Each raw material should be coded, and an inventory kept by a card index system. The cards may list other pertinent information concerning the purchase of each particular item, such as name of product, source of supply, address and telephone number of supplier, price, delivery charges, and total cost. As the plant batch cards are assembled from the production department, the total amount of each material used can be deducted from the card record to obtain the amount of material on hand.

If the company has sufficient background regarding purchases, figures for minimum requirements can be established for each item and reordering can become automatic when an operating minimum is reached. This procedure will tend to lessen the rush-order buying so common to the chemical industry. In the face of rising prices, it is sometimes desirable to carry a much larger inventory than is currently required, whereas a falling price market usually accounts for maintaining stocks at the lowest possible level consistent with operating schedules. The actual dollar savings which can result from wise and timely purchases is often the difference between profit and loss in the management of a plant.

Inspection of Raw Materials. As new raw materials are brought into the laboratory, evaluated, and found acceptable for plant use, a code number should be assigned and all the necessary physical and chemical constants should be recorded in a raw-material specification book. When this book is properly assembled, it is the fundamental source of information regarding all materials contained in the finished products.

Liquid raw materials which are received in tank wagons or tank cars are tested by the laboratory before they are pumped into the storage tanks. Other commodities are sampled after the shipment is received and are held in abeyance for laboratory approval.

General Procedure

The responsibility for the design of products which can be made with the facilities available in the plant rests with the development laboratory; a study of the manufacturing problems involved for each new item is essential. A thorough knowledge of processes and the limita-

tions of various kinds of equipment will determine the most convenient method of handling new formulas in production.

The processing of raw materials in mills for which they are intended can overcome many of the difficulties encountered in matching laboratory standards and will not upset normal operating procedure if handled according to a predetermined plan.

Choice of Equipment. The purpose of grinding is to obtain a satisfactory dispersion of pigment in the vehicle at the lowest overall cost per pound of pigment dispersed.

Since there is considerable overlapping in the field of application of each mill, it is natural that confusion exists as to the best type for a particular job.

Ball and pebble mills have the following advantages over roller mills:

> Lower labor cost—labor of less skill is required and no attention during grinding is necessary.
>
> Lower operating cost per gallon.
>
> No preliminary mixing required.
>
> Assured uniformity of grind throughout the batch.
>
> No loss of volatile solvents and negligible grinding loss.

Ball mills, as compared with pebble mills, can handle somewhat more concentrated pastes, attain the desired fineness in less time, and reach greater ultimate fineness, because of higher specific gravity of the grinding medium. These advantages, of course, result in lower costs. However, it is impossible to obtain as light a color with ball mills as with pebble mills because the paint is contaminated with steel from the balls as they wear. The ability of pebble mills to produce clean colors is probably the sole advantage of pebble mills over ball mills.

The superiority of roller mills lies in their ability to grind as fine as ball mills and to maintain the clean color obtained in pebble mills. Even this statement is subject to reservation, as many siliceous pigments, such as asbestine and silica, produce gray-colored paints on roller mills.

Roller mills grind heavier pastes than either ball or pebble mills, and they clean easily with only a small quantity of washing material. This advantage is appreciated in the making of paste-type products where no reducing vehicle for the paste is available for clean-up at the end of the run.

Roller mills are flexible in the size of batches that can be processed. A roller mill can grind batches of almost any size, whereas a ball mill is limited to pastes with volumes approximately 25 to 60 per cent of that of the empty cylinder.

High-speed carborundum mills are, of course, very effective for the quantity production of pigmented items where fine grinding is not too essential.

Paints can be divided into several groups for the purpose of selecting the proper method for the manufacture of each type:

Paste Paints. Heavily pigmented products are first mixed, then ground to the desired fineness on three-roller or high-speed carborundum mills. Filling is usually done from the apron of the mill into the proper-sized containers. Some pastes do not require grinding and are filled directly from the mixer into cans, kits, or drums.

Barn and Roof Paints, Exterior House Paints, and Oil Primers. Oil paints are made in pebble mills or mixed and then loosely ground on three-roller or carborundum mills.

Flat Wall Paints. Products of this nature can be made in pebble mills or ground on three-roller or carborundum mills.

Semigloss and Gloss Paints. These coatings can be produced in pebble mills or can be ground on three-roller mills to obtain good, uniform grinding.

Gloss Enamels. This group of products should be ground on three- and five-roller mills or in steel ball mills in order to attain the necessary fineness of grind.

High-Grade Industrial Enamels. White and colored enamels can be ground on three- and five-roller mills, although colored enamels can often be produced more efficiently in steel ball mills.

After the paste is ground, it is then reduced with oil, varnish, or solvent to the ready-mixed form in a thinning tank and is either filled as made or tinted to the required color. During the entire process, care and cleanliness in the handling of the batch are important. Any careless operation is likely to show up in the finished paint. Skins, grit, and unground materials will have to be removed before filling. Exterior paints and flat wall coatings require very little in the way of clarification. A coarse-wire strainer, probably 20-mesh, is all that is needed to remove skins that may be in these products. Gloss enamels require more care and can be strained through 60-wire mesh or cheesecloth. The quality of industrial enamels is most important, and any foreign material such as specks or grit should be removed by straining through cheesecloth, cotton batting, or silk. A centrifuge is recommended to take out the finer grit which may be difficult to remove in any other way.

Varnishes which have been developed in the laboratory require special consideration when they are converted into plant-size batches.

The cooking of varnish involves chemical reactions which depend on accurate time and temperature conditions during the process. The first plant batch should be made by an experienced operator under the supervision of the laboratory, and the finished varnish should be carefully checked against the laboratory standard for color, viscosity, drying time, and other properties before full-scale production is scheduled.

Plant Efficiency. As a matter of sound economy and to avoid costly errors, formulas should be constructed with the lowest number of ingredients necessary to achieve the desired results. The amounts of the principal ingredients should be in multiple units of the original packages or containers in which the raw-material inventory is carried to reduce errors and waste of time and materials in handling. Whenever possible all production batches should be planned so that the complete tank capacity will be utilized. Unnecessary expenses are increased when two half-size batches are run one week apart. After the laboratory has worked out the best combination of ingredients for the mixing, grinding, or cooking operations, the plant must then use every possible aid to increase efficiency and speed up production through scheduling, routing of materials, and time and motion studies.

Production Planning

Manufacturing costs and operating schedules can be controlled by consideration of the factors involved. Plans for the effective utilization of labor and materials should be established in advance of actual production.

Preparation. Several provisions which have a direct bearing on smooth operating procedure include a system to ensure adequate supplies of raw materials and intermediate bases, convenient storage facilities, and distribution of manpower.

As explained earlier in this chapter, the maintenance of a raw-material inventory can best be accomplished through a perpetual stock record. When a batch ticket is issued, the amount of each raw material called for in the formula is subtracted from the amount shown on the individual cards as residual inventory. The correct operation of a perpetual inventory system will eliminate delays in production due to lack of raw materials since the accounting will be done before the batch ticket is released for manufacture. A minimum inventory figure for each item should be established. This order point for purchasing fresh supplies will vary since it is dependent on the consumption, availability, and time required for the delivery of the individual materials.

A simple example of a perpetual inventory card is shown below:

Perpetual Inventory Card

	CODE NO. XXX		Magnesium Silicate	
	ORDER POINT: 1500 lb		SUPPLIER: John Doe, N.Y.	
Initial Purchase	4000 lb	Batch 1693	493 lb	5-3-50
	3507 lb	Batch 1697	507 lb	5-4-50
	3000 lb	Batch 1701	1560 lb	5-5-50
	1440 lb	Ordered*	4000 lb*	5-5-50*
		Batch 1703	650 lb	5-6-50
	790 lb	Batch 1705	890 lb	5-7-50
	−100 lb*	Received	4000 lb	5-7-50
Balance	3900 lb, ect.			

* Red ink.

The perpetual records should be reviewed periodically to determine if the order point should be raised or lowered. In the example given above, the order point could be raised somewhat since a minus balance was shown on 5-7-50. However, Batch 1705, which called for 890 lb of the material in question and consumption of which reduced the inventory to a negative balance, probably would not have been scheduled for manufacture until the following day and by that time the shipment ordered two days before would have been received. However, if too many minus balances appear, it is a good indication that the order point is out of line and should be raised. On the other hand, if an item does not show complete turnover in 30 days under normal conditions, it can be assumed that the order point is set at too high a figure and should be lowered.

With an index card system showing the consumption and other data, inventories of semifinished materials such as tinting pastes and bases can be maintained in much the same manner as described above for raw materials. The importance of keeping these items in good supply is obvious. Selection of the amounts and types of each tinting paste calls for careful analysis of the products being manufactured. Three basic types of pastes are those dispersed in (*a*) medium-oil-length varnish, (*b*) medium-oil-length alkyd, and (*c*) linseed oil.

Pastes may be as concentrated as possible in order to hold the amount on hand to a minimum, but they should be fluid enough for ease of handling and blending in batches to which they are added.

An orderly arrangement for the storage of raw materials is positively required. Pigments should be separated according to colors and located

so that those most commonly used are easily accessible to the mixing department. If it is at all possible, black pigments should be segregated in a closed, but well-ventilated room.

Grinding and reducing vehicles which are consumed in quantities are usually transferred through pipe lines from storage tanks to a central location for weighing or metering into batches. The withdrawal of liquids from drums frequently justifies a rack and temporary fittings with gate valves or spigots.

All packages and containers should be plainly marked so that even the inexperienced workman can identify them correctly either by code or name.

The need for proper balance in the distribution of manpower is obvious. On the basis of a plant manufacturing 500,000 gal per year, the ability to shift employees from one job to another has an important influence on operational procedure. Flexibility of manpower is the keystone to successful management in a plant of this capacity. Each plant has its own characteristics in this respect, but the fundamental objective is, through planning and supervision, to have the personnel actively engaged with their duties at all times.

Scheduling. Production schedules should be based on a definite color pattern. Batches of whites should be followed by tints, light colors, and finally, dark shades. Dark colors can be followed by lighter shades of the same hue, these by bases for light tints, and, finally, whites can again be scheduled. A system of rotating batches according to shades will eliminate what would be necessary otherwise, thorough cleaning of equipment between runs. This method of scheduling applies to the mixing, grinding, thinning, and filling departments. Proper planning in this respect can save both time and labor.

A schedule sheet or chart should be prepared so that pertinent information regarding the status of batches and equipment can be observed at a glance. This flow sheet can show the following data:

1. Mixers, mills and tanks identified by number.
2. Order number.
3. Date received.
4. Product name.
5. Size of batch.
6. Batch number.
7. Formula code.
8. Daily progress columns divided into A.M. and P.M. sections. (These can be arranged to show anticipated and actual progress of each batch.)

A record of this nature provides the factory office with working knowledge of both occupied and idle equipment. It not only is the key to successful operations but also will furnish the answers to many inquiries from the sales and shipping departments.

When production is being planned, adequate time should be allowed for each manufacturing operation. Erroneous estimates in production schedules are as bad as no estimates at all, since they either cause equipment to lie unnecessarily idle or clog some departments with too much work while other units are slack. All contingencies should be considered when schedules are prepared, and ample time must be allowed for the following basic steps: (1) assembling of raw materials; (2) mixing; (3) grinding; (4) thinning; (5) tinting; (6) checking and testing; (7) filling, packing, and shipping.

The batch card should always show the type of mill to be used for grinding and the average rated capacity. From this information the grinding time can be accurately estimated.

The time required for thinning will depend on whether thinners are metered, measured, or weighed from tanks or drums.

Tinting time will vary from batch to batch because of any one of the following factors: (*a*) Color of finished batch; i.e., blued whites require less time than more complicated colors, such as deep-tone grays and greens where two or more tinting bases are employed. (*b*) Type of material, i.e., automotive enamels will require much closer color matching than house paints. (*c*) Drying schedule of finished material; i.e., more changes can be made on fast-drying lacquers and baked enamels per unit of time than on straight air-dry products which may require overnight to develop true color. (*d*) Experience and ability of tinters.

Checking and testing time for batches in process should be estimated from data shown on the formula specification. Sufficient time should be reserved for the laboratory to run the required tests for each product. This is especially true when the manufacturer is dealing with customer or government specifications. Many of these specifications tests are rigid and take from 3 to 5 days to complete. The fact that some tanks are non-productive for this period is a serious matter, and the time required for the tests must be taken into consideration in the making of a schedule for such items.

Time allotment for filling, packing, and shipping presents no particular problem. With the proper equipment, filling and packing operations can be standardized for whatever type of material is being filled. A few time studies in these departments will provide information on which general schedules can be based. When these operations are being scheduled, it is necessary to know the size of containers to be filled and

type of packing desired. Obviously, filling and packing in half-pint bottles is considerably slower than in gallon cans.

Plant Capacity. The production capacity of a plant is largely determined by the type of products being manufactured. A plant of average size should be flexible enough to manufacture a large variety of products, such as primers, flats, semigloss and gloss enamels, exterior paints, and certain industrial specialties. Each of these, of course, requires different lengths of time to process and various types of equipment. Equipment recommendations have been discussed elsewhere in the *Manual.*

Some additional consideration, however, must be given to the mixing and grinding time required for the various types of materials before an attempt can be made to establish figures with respect to anticipated volume. Although mixing is an important function and one closely allied with grinding in paint manufacture, this phase of the complete operation is less important from the standpoint of time consumed.

Since pre-mixing is necessary to roller-mill grinding, the capacities for each operation are interdependent. The most efficient roller mill available will not operate to full capacity unless adequate mixing equipment has been provided to keep it busy. Loading mixers to their rated capacities will assist materially in maintaining high production figures. Mixers are usually set up in pairs for each roller mill to operate as follows: mixer A is loaded first, and, while it is operating, mixer B is loaded. While mixer B is running, A is discharged to the mill and will be ready to be refilled while B is being discharged. While B is mixing and A is delivering to the mill, the interval is used to obtain raw materials for the next cycle. It is obvious that mixer-delivery capacity for each mill should be at least equal to the final mill capacity for the fastest-grinding material that may be produced on any given unit.

Steel ball and pebble mills present no particular problem in respect to pre-mixing, and predictions for this type of equipment are considerably more simple than for roller-mill production because the capacity is directly related to the size of mill and operating hours.

When schedules are prepared, it is desirable to group the various products into separate classifications according to the grinding equipment required for each item.

From accumulated knowledge and experience for mills associated with the different types of paints, mill-rate estimates can be obtained which can be used as a basis for scheduling mill production. These rates can only serve as a guide, and actual grinding rates should be set up eventually for each formulation. Production capacities are materially influenced by the type of pigments requiring dispersion. Hard-

grinding pigments such as organic reds, maroons, carbon blacks, iron blues, and siliceous inerts take longer to grind than whites, chrome yellows, and soft inert pigments which disperse rather easily.

PRODUCTION CAPACITIES OF ROLLER, BALL, AND PEBBLE MILLS

Product	Mill	Average Paste Rate	Approximate Amount Finished Paint
Flats, (white)	250-gal pebble	150–200 gal/24 hr	200–350 gal/24 hr
Flats, (solid colors)	300-gal steel ball	180–250 gal/12 hr	250–450 gal/12 hr
Flats	13- x 32-in. 3-roll	75–150 gal/hr	150–250 gal/hr
Semigloss	250-gal pebble	150–200 gal/24 hr	250–400 gal/24 hr
Semigloss	13- x 32-in. 3-roll	20–30 gal/hr	40–60 gal/hr
Semigloss	300-gal steel ball	180–250 gal/18 hr	300–500 gal/18 hr
Gloss enamels	13- x 32-in. 5-roll	5–15 gal/hr	20–50 gal/hr
Gloss enamels	300-gal steel ball	180–250 gal/30 hr	400–600 gal/30 hr
Exterior paints	13- x 32-in. 3-roll	50–125 gal/hr	75–250 gal/hr
Exterior paints	250-gal pebble	150–200 gal/24 hr	250–350 gal/24 hr
Primers, etc.	300-gal steel ball	200–250 gal/18 hr	300–400 gal/18 hr
Primers, etc.	13- x 32-in. 3-roll	50–125 gal/hr	75–200 gal/hr

Tank capacity for each unit should be considered when production is being planned. An accurate tank layout should be available so that the production flow sheet will indicate when and where the ground batch will be discharged. Production must be based on total tank capacity and filling facilities, as well as on the output capacity of milling and grinding equipment.

Dispatching. The basic raw materials which have to be routed through the plant are solids and liquids. Unfortunately, the number and variety of both limits the application of engineering principles to relatively small-batch intermittent operations. Obviously, a major step toward efficient handling will be taken if lines can be concentrated to require greater volume per individual item. Some manufacturers are taking advantage of this in the large-scale production of white goods, varnish vehicles, and lacquer products. The problem is not so easy with a general line of shelf goods, although long runs on seasonal products offer an alternate plan. For example, the production of oil paints exclusively for two weeks or a month will allow handling technique to operate at peak efficiency in the plant. This system can also be applied to enamels, flats, pastes, and other products.

Specific suggestions for the dispatch of materials follow:

Liquids. 1. Vehicles should be pumped to storage tanks where they can be piped to mixing and thinning floors and drawn by gravity when needed.

2. A central dispensing and weighing station for portable or stationary thinning tanks is most convenient.

3. For accuracy, metering or weighing-in systems are preferable to measuring by volume in containers.

4. Transfer of very viscous liquids should be overcome by raising the temperature or by blending with other components to reduce the viscosity. Heavy oils and synthetic solutions from near-by suppliers can probably be delivered warm in tank wagons.

5. Management should insist on the fewest liquids possible whether these are furnished by suppliers or are of its own manufacture.

6. Teamwork between laboratory and production departments can eliminate many bottlenecks in the plant.

Solids. The transfer of solids to point of use requires more labor than the handling of liquids. Obviously, any approach to the problem will be concerned with reducing physical effort, such as is recommended below:

1. Storage of fixed amounts per unit should be on movable platforms and at the nearest possible location to mixing or operating floor.

2. Floor and platform scales for weighing should be where pigments are located.

3. A central weighing department where pigments are scaled into portable bins and the dry blends are wheeled to the mixing pugs or ball mills for dumping has certain advantages.

4. Monorail conveyor systems and electric hoists for the transfer of solids to mills or kettles are convenient.

5. The many applications of compressed air as a means of effective handling of materials in and about a paint plant should not be overlooked.

6. Again, the cooperation of the laboratory can do much to simplify the handling of solid materials in production by limiting the variety of ingredients per formula and making the batch sizes consistent with mill capacity and in multiples of package units from storage.

Finished Goods. The detailed operations required for transfer of finished products into the shipping room will not be discussed, but, obviously, the work must be kept moving and off the floor. Whether the filling is done by hand or machine from thinning tanks or clarifiers, the filled packages should be capped, labeled, cartoned, and in transit by conveyor or otherwise toward the stock room once the packaging operation is started. The filling, labeling, storage, and/or shipping departments should have advance notice before batches are completed so that they will be fully prepared to handle the work when it reaches their hands.

To summarize, it is evident that the shortest distance and quickest time between the receiving dock and shipping platform is a straight line.

That line can be either perpendicular, horizontal, or a combination of both, depending on individual plants and ideas of layout. Whatever contributes to keeping the line straight and the goods in motion encourages efficiency and better quality of product.

Effective routing or dispatching of materials through the production cycle requires study from many angles: (1) formula design, (2) projected sales plans, (3) availability of materials, (4) capacity and adaptability of existing equipment, (5) plant layout, and (6) management's approval of a program that may involve heavy inventories.

Production Control

Progress Charts. As outlined in the previous section, a chart showing the schedule of batches in process should be prepared and made available to each department for systematic planning of the work anticipated. Whenever a change in status of a batch takes place, the next department should be notified so that necessary adjustment in the original schedule can be made. The superintendent should check at least twice a day with each department, so that the progress chart in the factory office will reflect the true state of affairs in the plant. Knowledge of the exact position of batches in production at all times is positively essential for the proper supervision of plant operations.

Inspection and Quality Control. One of the requisites of any manufacturing unit is the control point. In the paint industry, approval of production batches is in the hands of an inspection department and the reputation of the company is dependent on its decisions. The control laboratory has the first opportunity to examine exactly the product that the customer will apply later. Inspection should be critical and from the customer's point of view. Rejections and adjustments before filling are much easier to handle than complaints and returned merchandise. An appropriate record of batches tested should be kept on file by the inspection department.

Control tests can usually be divided into two groups: Those which may be run on every batch include viscosity, working properties (brush, dip, or spray), weight per gallon, non-volatile solids, gloss, drying, fineness of grind, and color. Those which should be checked periodically, possibly every fifth batch, include hardness, hiding, settling, reflectance, and any special tests desired. When manufacturing specification products, it may be necessary to run all tests on every batch; the omission of any tests should be at the discretion of top management.

Samples from batches in process should be submitted to the control laboratory as a matter of routine by the following departments:

METHOD																				FORMULA NO:
MINIMUM																				SUPERSEDED BY
MAXIMUM																				REPLACES:
DATE	BATCH NO.	GAL	VIS.	WORK-ING	WT.	NON VOL.	GLOSS	HARD-NESS	DRY	HID-ING	SETT-LING	GRIND	MILL NO.	GAL PER HOUR	MILL PASTE VIS.			COLOR MATCH	O.K BY	REMARKS. (SHOW CUSTOMER'S NAME IF SHIPMENT IS MADE TO OTHER THAN ORIGINAL)

Fig. 45. Inspection record.

(*a*) Grinding department: In roller-mill grinding, a composite sample of the paste from three sections of the apron should be tested as the operator has the mill set for the batch run. After approval of the fineness of grind, the adjustment of the rolls should not be disturbed and only periodic checking by the operator will be necessary.

When pebble or steel ball mills constitute the processing equipment, samples should be checked at the conclusion of the established running time and before thinning so that additional grinding time can be allotted if required.

(*b*) Thinning and tinting department: After tinting, a sample of the batch should be sent to the laboratory for all check tests.

(*c*) Filling department: A retain sample should be taken during the filling operation, checked to determine if the weight per gallon is consistent with the sample from the thinning and tinting department, and then filed for future reference with proper marking for identification.

Where temperature is a factor, with particular reference to viscosity and weight per gallon, samples should be tested at 25°C, which has been accepted as a convenient standard throughout the industry.

Samples should always be checked for color against adopted standards, which may be in the form of dry chips, ceramic plaques, or wet samples. For many products dry chips are satisfactory if they are kept clean. Porcelain or vitreous enamel plaques are more difficult to match, although they are definitely superior in color retention. Wet samples often have a tendency to drift from the original color, and such changes must be reconciled and corresponding adjustments made from time to time.

The method of application has an important bearing on the color, drying, and general appearance of paint products, and test samples should be applied in the manner that will be used by the customer: brushing, dipping, or spraying. Parchment panels or heavy paper stock which has been sized with a suitable coating and cut to uniform dimensions, 3 in. wide and 8 in. long, is a satisfactory surface on which to test materials; it can be kept as a visual record of each batch. Tin or steel panels with dimensions varying from 3 to 4 in. wide by 5 to 12 in. long are convenient for testing industrial items which may be applied by spraying, flowing, or dipping, and either air dried or baked.

For best results color comparisons should be made in the light from north windows, supplemented by artificial daylight units when the natural light is insufficient or not readily available.

The functions of the control laboratory must be conducted from the viewpoint of speed-with-care. Sufficient personnel and testing equip-

ment should be provided in order to avoid costly delays and to lessen the possibility of making decisions under pressure during peak production periods.

Maintenance

When a systematic procedure for good housekeeping and maintenance is followed, production control becomes less difficult, operating costs are reduced, fire and accident hazards are overcome, and both the quality of finished products and volume output are increased.

Every plant should have an adequate safety and accident-prevention program. Weekly plant inspections, by a competent person, are desirable with specific attention to the guarding of operating equipment and the condition of hand tools; housekeeping, including locker rooms, lunch rooms, and toilets; use of goggles, respirators, rubber gloves, or other protective equipment; safe methods of handling materials; condition of elevators, stairways, and ladders; condition and availability of fire-prevention equipment; condition of electric wiring, switches, and transformers; and any other items which may affect the safety of employees or operating efficiency of the plant.

In addition to this weekly inspection, a monthly inspection should be made by a committee of supervisors. A written record should be made of all inspections, so that items requiring attention may be followed through to completion. It is a good plan to vary the membership of the monthly inspection committee to maintain interest and get the advantage of different viewpoints.

Maintenance of buildings and manufacturing facilities is most important. A capable supervisor or master mechanic in charge of this work will save his salary many times over by keeping plant and equipment in good operating condition, thus avoiding costly breakdowns which delay production schedules.

The chief responsibilities of the engineering or maintenance department have been described as follows:[1]

1. To keep the housing (buildings) in such condition that equipment always will be protected and people will have heat, light, water, sanitary facilities, protection, and any other services that go to make up the right kind of working conditions.

2. To improve the housing as advanced practice in production makes such improvement necessary.

3. To provide the power necessary to operate the productive machines, by the most economical methods of distribution and application, and to see that there are no power failures which would interrupt production.

4. To provide the services, normal or special, necessary to production, such as air, water, gas, oil, ventilation, air conditioning, or others.

5. To see that the production machines themselves are always in good condition to turn out products of the proper quality in the proper quantity.

6. To work jointly with the production forces to make certain that there is available and in service at all times the handling equipment necessary to move materials through the productive process at such speeds as will prevent idle time for any production equipment.

Care of Equipment. The machines used in the paint industry are heavy duty and rugged. If given proper care and normal usage, they will last almost indefinitely. A clean machine usually indicates a well-cared-for unit. Dust and dirt are the major causes of wear; eliminate these and the life of the machine is greatly increased. Usually the operators can be held responsible for greasing the equipment (with the exception of motors). Maintenance men should handle greasing and oiling of line shafting and motors. Overlubrication on some types of high-speed ball bearings is as serious as insufficient grease; therefore, an experienced person should handle this type of work. All equipment should be checked at least once each month for lubrication. Such a check-up will materially reduce maintenance costs. If abnormal sounds develop while a machine is operating, the cause should be investigated immediately, without waiting for something to break.

Pumps should be inspected and repacked periodically, depending on the kind and amount of service involved. Paint is rather severe on pumps, and wear must be expected; but they will last much longer if they are washed after using. The foreman should observe any fluctuation that may develop in the delivery rate and notify the maintenance crew if the decrease in output becomes serious. It is well to keep a few extra pump parts on hand for quick changes when necessary.

Piping and valves in the plant probably require as much attention as anything else, particularly those employed in the manufacture and pumping of varnishes. Where it is practicable, the absence of driers in the varnishes will cause less trouble, and blowing inert gas through the line or keeping the line filled with liquid will reduce the skinning and building-up of coats in the pipe. When the lines do become clogged, the cheapest and easiest way to handle the problem is to take them down and burn them out or replace them entirely. When pipe is being installed, as few 90-degree bends as possible should be involved, since the elbows restrict flow and drainage and encourage future trouble. Most pipe fitters use too few unions, and extra work is created when the

removal of lines becomes necessary. Cast-iron elbows are easy to crack and may save a great deal of labor when pipes are torn down. Furthermore, cast fittings never bend out of round, and, thus, one cause of leaks is eliminated. It is important that the work of the maintenance crew shall be first class; for example, piping should be properly supported without resort to improvised or temporary methods. Every company will benefit by having at least one good all-around mechanic on the payroll.

In the average plant, electrical work should be let out to industrial electrical contractors. Faulty wiring may cause damage to equipment or be instrumental in starting a fire.

Simple carpentry can be done by a handyman, but any large project should be farmed out to a contractor who usually will complete the work faster and at less expense than inexperienced factory help.

Care of Buildings. Many paint manufacturers labor under the mistaken idea that the paint plant must be dirty, owing to the nature of the business and the materials handled. New buildings are, of course, easier to keep clean than those which are old, but good housekeeping can be accomplished in either type. Essentially, good housekeeping is a matter of cleaning up as soon as spills occur. This is primarily the responsibility of the worker; it requires constant attention and a desire on his part to have a neat and orderly plant. If the floors are kept clean, the walls and ceilings kept painted, and the lighting is adequate, there will be a noticeable improvement in plant efficiency. Plenty of light creates a cheerful atmosphere and more work is the result.

Floors can be a source of trouble due to the movement of heavy portable tanks which create excessive wear. Checkered steel plates over the areas of heavy traffic provide a satisfactory solution to the problem. The upkeep of buildings is generally handled by contractors who are equipped to make repairs, do the painting, and take care of the roofs, although inside painting can often be done by the plant personnel during dull seasons.

Maintenance Check List. A list of items has been published as a guide for systematic plant inspection and is reprinted here by permission:[2]

Building.

1. Keep walls clear of unplanned storage of wire, fittings, rags, etc.
2. Remove notices, posters, etc., from walls and keep only on centrally located bulletin boards.
3. Vacuum cleaning of walls at least every three months has been found best procedure.
4. A check of walls for reflective value in illumination at least once

a year is advisable; and repainting when light reflective values drop low is advisable. Most local electric company engineering departments will do this without charge.

5. Keep floors clean and well repaired. Cracks and breaks in floors should be repaired as soon as they occur, even under machines.

6. Make certain machines are not dripping oil or grease on floors; if so, provide catch pans.

7. See that the system for cleaning and rubbish removal is operating so that the job is done daily and done efficiently.

Plant Layout.

8. Aisles and passageways should be kept clear; painting stripes to denote areas in which clear traffic is to be maintained is advisable.

9. Check to make certain exit areas are always clear; that emergency doors are operating easily and efficiently; that access to these exits can always be obtained speedily and without chance of blocking.

10. Check all stairways at least once a week to make sure no structural faults have arisen, that they are being kept clear of obstructions, and that all dark areas thereon are well lighted.

11. Drinking fountains should be washed and cleaned daily and a system of self-maintenance by employees made a part of the plant routine.

12. Dispensers of bottled drinks and confections should be set in areas where congestion will not affect plant routine; if they are not so placed at present, they should be moved.

13. Safety installations should be inspected at least once a week for assurance that they are in operating order as well as for cleanliness.

14. Fire-protection equipment should always be accessible, and its accessibility should be made a part of the maintenance check-up.

15. Fire extinguisher content labels should be inspected at every maintenance routine and kept fresh.

16. Fire protection equipment should be included in the maintenance cleaning routine of the plant.

Equipment.

17. Every major unit in the plant should have a maintenance record card, and this card, or a tally-sheet, should be taken along on every maintenance check-up.

18. Dirt and dust accumulations should be removed from machines daily and a thorough and complete inspection made at least once a week.

19. Equipment painted surfaces should be checked at least once a

month to make sure paint still protects metal surfaces in preservation and provides glareproof surfaces.

20. Floor bolts of machines should be checked at least once a month, for loose bolts can result in excessive vibration with resultant damage and possible accident hazards.

21. Power leads to each unit of equipment should be checked on every routine maintenance check-up and, when the slightest sign of wear appears, should be immediately replaced.

22. Guards on equipment should be checked not only for rigidity and appearance but given a close examination to detect the source of possible future breaks · · · and repairs made *immediately* when these are discovered.

23. The maintenance check should also include all tools and small units and these should be checked not only for their own condition but to make certain no one has slipped into the habit of leaving them around on machinery and heavy equipment.

24. A thorough check to make sure that no employee has acquired the very bad habit of leaving things lying around on machinery and equipment should be a part of every maintenance check-up routine.

25. "A place for everything and everything in its place" should be a rule in every organization, and the maintenance check-up should include making certain that the rule is being followed.

26. The maintenance check-up must also take into account whether or not the people in the plant itself are kept aware of their part in day-to-day maintenance of every piece of equipment they are using.

27. Provision should be made for the discovery of broken, worn, and obsolete tools and equipment, during every maintenance check-up, and a record of these made for immediate replacement by the department in charge.

General.

28. Every maintenance check-up should make certain that there are plenty of receptacles for scraps of all kinds at different points in the plant and that these are being used.

29. Used rags and waste should be removed promptly for washing and reclaiming as they always constitute fire hazards.

30. At least once each 6 months all electrical circuits should be checked closely and replacements of any worn parts or wiring made immediately upon discovery.

31. Out-of-season equipment should be checked when idle (i.e., air conditioning in winter, heating units in summer) as this is the ideal time at which to make needed maintenance repairs.

32. A regular check-up of storage areas is advisable to make sure lighting and protective equipment are in order and that good storage procedure is being followed therein.

33. Outside of buildings should be checked for needed maintenance work at least once every 3 months.

Installation of Equipment

Men who are experienced in handling heavy equipment or who have rigging knowledge are not usually carried on the payroll of small plants. Because of this fact, it is often necessary to hire outside millwrights to move and install heavy machinery. Floor loads must be considered, and, to avoid overloading and vibration, it may be necessary to secure the services of a consulting engineer.

Before selecting the exact location for new units, certain preliminary considerations are desirable which often can be visualized by making a plan of the floor to scale and placing on this plat replicas of the operating equipment in the form of cut-outs made of heavy paper. By shifting the cut-outs to various locations on the floor plan, the most satisfactory and efficient arrangement of the different units can be determined. The overall perspective of plant operations which may be obtained by this method of advance planning will bring into sharp focus the objections to certain locations for new equipment and may even suggest desirable changes in the existing layout.

Processing machinery should be grouped together to achieve the highest efficiency. The routing of raw materials and their normal flow as products in process will continue then along established channels throughout the various stages of production.

Other precautions which affect the placement of equipment include the consideration of permissible floor loads which should allow 200 to 250 lb psf for the average production area and up to 350 lb psf for storage areas, with special supports provided for heavy units.

Accessibility to power and water outlets, adequate ventilation and lighting facilities, and provisions for safe working conditions throughout operations are essential requirements that influence the placement of plant machinery.

Mechanical Improvements

Many ingenious devices have been developed and attached to standard manufacturing units by the production staffs of individual plants. Very often the best suggestions for such improvements come from mem-

bers of the working crew who have intimate knowledge of the operating conditions.

A suggestion system with suitable prizes for approved ideas can be of great help. Forms should be provided with boxes in various locations where suggestions may be deposited for collection and review at regular intervals. A nominal sum can be paid for approved suggestions, with special prizes for those of greater value. Many helpful ideas will come from the man on the job if he is given an opportunity to express himself and is adequately rewarded for worth-while improvements.

Obviously, the same alterations in operational procedure or processing equipment will not apply to all plants, and it would be impossible to suggest any more than a few types of homespun gadgets that have been used to increase efficiency or overcome local production problems:

High-speed carborundum or stone mills are equipped with small hoppers that have been conveniently replaced with one of larger size to take a full batch of grinding base. This change is equivalent to adding another mixer on the floor above, and it can be done locally at very little expense.

Roller mills have a tendency to produce very poorly ground dry material at the ends of the rolls. These are commonly called dry ends or tailings. This material, if allowed to get into the batch, may spoil the grind. Some operators place a sight-glass oil cup over the ends of the feed roll and allow linseed oil to drip on the roll from these cups. Another method of removing the tailings is to slot the apron on each side and use a small piece of angle iron which can be adjusted on the apron to guide these dry ends to the slot which then drops the material into a gallon bucket.

Ball and pebble mill gates or covers are extremely heavy, and some simple method of handling them is essential. A wooden, homemade jack will do the trick. Two 3-ft lengths of 2 $\times$ 4-in. lumber are laid out parallel and spaced about 8 in. apart with two 1½-ft vertical lengths fastened and braced on each of the first two with provision for a bolt through the two vertical pieces near the top. Another 3-ft length is mounted on the bolt between the two uprights with the hole in this piece only 12 in. from the end. A sling is used from the short end to the gate, and, with the leverage obtained, the operator is able to easily lift a relatively heavy gate.

A counting mechanism for recording the number of revolutions when a mill is operating has many advantages. It can also be set to shut the mill off at a predetermined number of turns. Such an automatic shut-off is often desirable for some types of products.

When pumps are used to unload pebble or steel ball mills, some diffi-

culty is experienced if small balls get through the strainers and into the pump; serious damage may be the result. This trouble can be eliminated by placing a line trap ahead of the pump. The trap is a very simple affair. A metal container, through which the feed line from the mill enters, has a baffle extending downward between the inlet pipe and the outlet pipe which are located on opposite sides of the baffle and near the top. All material entering the metal container must pass under the baffle, and any heavy material such as steel balls or pebbles will drop to the bottom and will not pass through the pump.

The disposition or recovery of cleaning and waste solvents that accumulate in paint and varnish plants has always been a problem. The method most widely used is to allow the dirty solvent to stand in settling tanks or drums, and then to decant it for thinning asphalt varnishes, dark Japan driers, or barn paints. Some companies have a solvent still in operation which has proved very satisfactory. Low pressure steam, which is always available, is used in the process. The dirty solvent is decanted in a series of three settling tanks and then run through the still.

Obsolescence

The wheels of progress grind slowly but surely, and eventually the present methods of manufacture must be replaced by those which are more modern.

Plant operators are usually slow to make drastic changes in equipment. This is only natural because of production delays and the expense involved. As has been shown, only a few pieces of production equipment have been recommended to produce 2000 gal of paint per day. To accomplish this same job with old style, slow-speed stone mills of a generation ago, approximately 30 mills would be required. Therefore, it is wise to convert to new equipment as it is developed and accepted by the industry.

Do not confuse obsolescence with old and poorly conditioned equipment. Perhaps the old roller mill can be redressed. If so, the reconditioned machine is almost as good as a new piece of equipment. In the event that a machine is obsolete and improved equipment is available, take the time and trouble to make the change. It usually pays dividends. The company that allows its plant to run down to the point where all the equipment is old or obsolete finds its production falling off, costs going up, and its business eventually lost to more wide-awake competitors.

Management should keep up to date and modernize as far as prac-

ticable by giving careful consideration to improvements in machinery and plant accessories which will facilitate production.

ACKNOWLEDGMENT

The information received for this chapter from H. S. Mann for the Baltimore Paint and Varnish Production Club, F. C. Auwater, C. M. Frey, C. M. Jackson, and S. B. Levinson for the New York Paint and Varnish Production Club, and R. F. Brewster and A. T. Montanye of the Pratt and Lambert Company is hereby acknowledged with the sincere appreciation of the editors.

REFERENCES

1. Editorial, *Factory Management and Maintenance*, May, 1939.
2. Fair, E. W., "A Maintenance Check List," *Am. Paint J.*, p. 34 (July, 25, 1949).

OFFICIAL DIGEST BIBLIOGRAPHY

Atwood, K. F., "Mixing and Grinding," p. 252 (Sept., 1937).
Barkman, A., "Equipment and Methods for Manufacturing Paint," p. 630 (Sept., 1950).
Berger, L. F., "Operation and Care of Roller Mills," p. 36 (Jan., 1949).
Breyer, F. G., "Grinding," p. 13 (May, 1928).
Buckminster, P. D., "Factory Records," p. 13 (Dec., 1926).
Chamberlain, W. C., "The Invasion of Modern Technique in the Art of Pigment Dispersion," p. 663 (Sept., 1950).
Grant, W. J., "Roller Mill Equipment," p. 599 (Sept., 1949).
Higgins, M., "Pigment Grinding by Formula," p. 5 (Oct., 1928).
Hopkins, F. W., "Grinding of Lacquer Paste on High-Speed Roller Mills," p. 9 (Dec., 1927).
Horack, W. R., "Paint Mills," p. 250 (Sept., 1937).
Katinsky, H., "Man and Mill Hours," p. 300 (June, 1940).
Kropel, E., "Laboratory Control," p. 247 (May, 1938).
Lynch, W., "Mixing and Grinding," p. 244 (May, 1938).
McKim, W. A., "Roller Mill Grinding Lacquers," p. 8 (Dec., 1927).
McMenamin, J. F., "Grinding," p. 255 (Sept., 1937).
New York Club, "A Study of Pigment Dispersion," p. 977 (Dec., 1950).
Round Table Discussion, "Packaging and Shipping," p. 992 (Dec., 1950).
Round Table Discussion, "Plant Production Problems," p. 969 (Dec., 1950).
Round Table Forum, "Small Order Manufacture—A Serious Drain on Profit?" p. 1126 (Dec., 1950).
Sentman, M. R., "Roller Mill Grinding," p. 124 (Mar., 1941).
Stark, R. C., "Factory Management in the Paint and Varnish Industry," p. 26 (June, 1937).
Stark, R. C., "Production-Supervision and Costs," p. 297 (May, 1944).
Stearns, F. N., "Grinding of Lacquer Paste in Pebble Mills," p. 12 (Dec., 1927).
Sulzberger, F. L., "Good Housekeeping," p. 1 (Mar., 1928).
Trussell, E. H., "Grinding of Lacquer Paste in Pebble and Steel Ball Mills.," p. 9 (Dec., 1927).
Uhl, V. W., "A Torquemeter for Measuring Power to Plant Mixers," p. 885 (Nov., 1950).

ADDITIONAL FEDERATION OF PAINT AND VARNISH CLUB PAPERS

Baltimore Club, "Buhrstone Mill Dressing," *NPVLA Sci. Sec. Cir.,* p. 432 (Nov., 1933).

Baltimore Club, "Practical Mill Dressing Studies," *NPVLA Sci. Sec. Cir.,* p. 353 (Nov., 1934).

CDIC Club, "Putting the Varnish Laboratory Batch Into Production," *NPVLA Sci. Sec. Cir.,* p. 359 (Nov., 1934).

New York Club, "Lacquer Grinding on Standard Type Mills," *NPVLA Sci. Sec. Cir.,* p. 937 (Nov., 1928).

New York Club, "Pigment Dispersions," *NPVLA Sci. Sec. Cir.,* p. 313 (Nov., 1934).

Paulsen, H. A., "Relation of Production Men to the Purchase and Delivery of China Wood Oil," *NPVLA Sci. Sec. Cir.,* p. 623 (Nov., 1927).

Probeck, E. J., "Use of Present Equipment in Lacquer Manufacture," *NPVLA Sci. Sec. Cir.,* p. 293 (Oct., 1926).

Stauderman, A. C., "Factory Organization From the Production Man's Standpoint," *NPVLA Sci. Sec. Cir.,* p. 608 (Nov., 1927).

Toronto Club, "Lacquer Paste Grinding on the 3-Roller Mill," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 115, 1940.

Western New York Club, "A System of Minimum Test Requirements for Control," *NPVLA Sci. Sec. Cir.,* p. 327 (Nov., 1936).

Western New York Club, "Raw Material Testing in a One Man Paint Laboratory," *NPVLA Sci. Sec. Cir.,* p. 291 (Nov., 1937).

CHAPTER 6

MANUFACTURING OPERATIONS

PAINT MANUFACTURE

In the manufacture of paint and varnish products, a great number of operations are required to handle the raw materials (pigments, oils, resins, and thinners) as they are received from the vendors and to process them into salable paint products for the consuming public. The raw materials, after they have been tested and approved as conforming to the standard specifications set up, are then ready for the various steps of production. In the manufacture of varnishes, the resins and oils will be processed into various types of vehicles. In the preparation of paint products, pigments will be suitably dispersed in liquids which may be either manufactured in the plant or purchased from the outside as designated by the formula for each production item. The dispersion of pigments is accomplished in various types of mixing and grinding equipment which have been described in Chapter 2. After the pigments have been incorporated with the vehicle, the resulting pastes must be thinned or reduced to proper consistency by the addition of more liquids. In many cases, the batches will be tinted to match standard colors. After this phase of operations, paints or enamels must be checked and tested against established specifications and, only when they have been approved by the Control Laboratory, are they ready to be packaged into the various sizes of containers required by the customer.

In this chapter the various steps which make up the manufacturing cycle will be discussed. As a basis of discussion, it is assumed that the plant has a medium production capacity of 2000 gallons daily with a safety factor on the equipment for future growth and expansion.

Receiving and Storage of Raw Materials

The receiving and storage of raw materials is the first step in the manufacturing cycle. This department should be so located that there is easy access for truckload or carload shipments. When the raw materials are received, suitable means for checking the weights, gallonage, or count should be available. A proper system of sampling all incoming products should be set up so that each and every shipment of raw ma-

terials is tested by the Control Laboratory to ensure conformation to raw material specification standards. When the shipment has been approved, it should be put into dry raw material storage or liquid storage tanks.

To facilitate the handling of dry stock and to make use of the optimum storage space which is consistent with floor load capacities, items in bags or cartons should be placed on pallets which can be stacked one on top of the other by means of a suitable portable type of tiering-fork lift truck. The investment in a piece of equipment such as this will soon pay for itself in the manpower labor it saves.

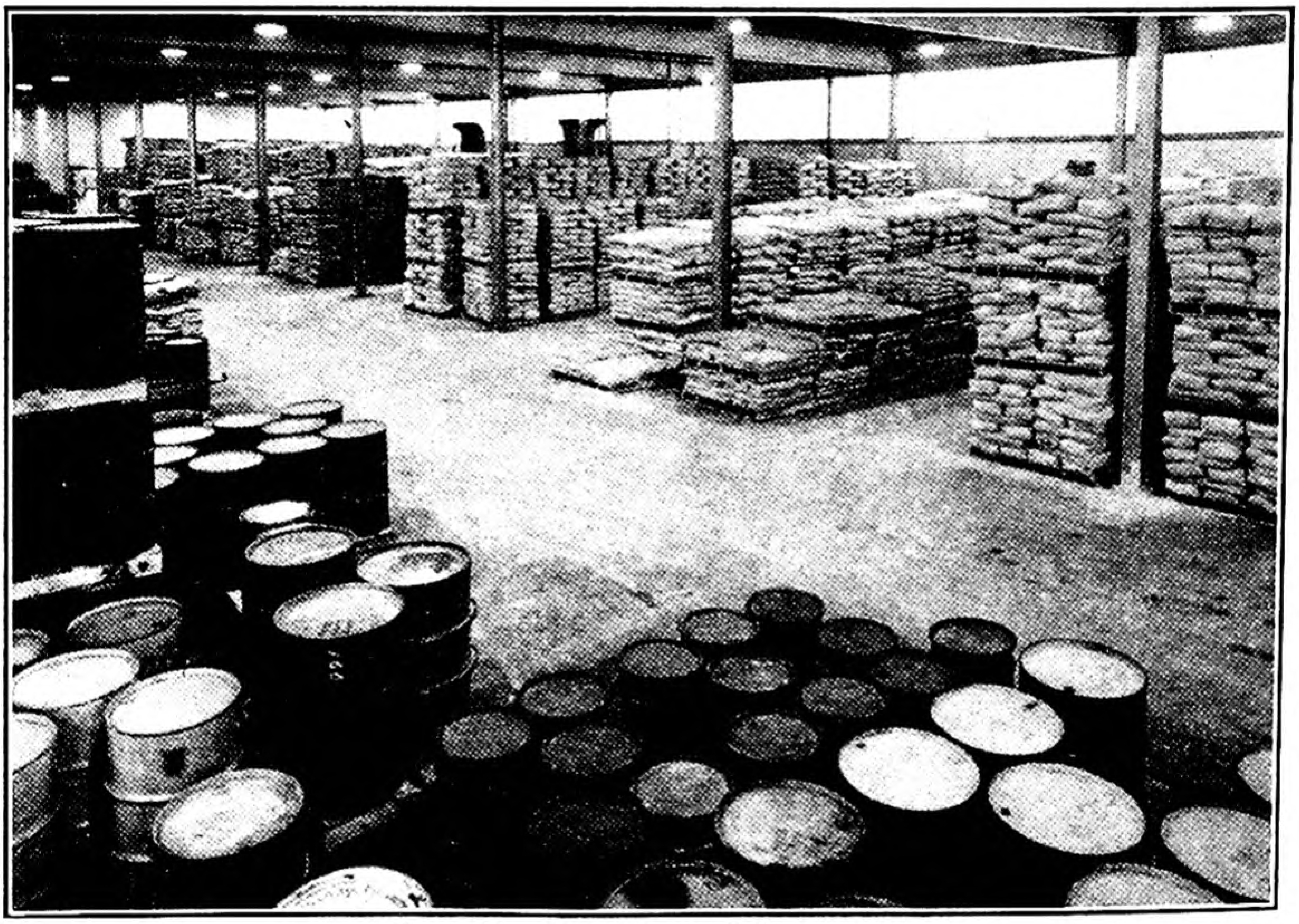


FIG. 46. Raw material storage.

Handling equipment which is explosionproof is recommended because, in a modern plant, the vapors of various types of solvents present a fire hazard that requires more than average safety precautions.

All the raw materials should be coded with identifying numbers which correspond to the code numbers used in the formulas on the batch cards or shop tickets. They should be stored by these numbers to eliminate mistakes when batches are being assembled, and also to aid in the counting and checking for inventory control purposes.

When the raw materials are required by any of the various departments, it is a very simple matter to take a pallet load down from the storage stock piles by means of a tiering-fork lift truck. The material

can then be transported to the department requiring it either directly by means of the tiering-fork lift truck or by having the pallet placed so that an electric lift or hand lift truck can remove the skidload to the proper department.

The storage of the various types of containers and cartons for packing should also be palletized for ease of handling.

Bulk liquids should be transferred by pumps and pipe lines directly to storage tanks which may be located underground, above ground, or inside of the plant, as desired.

In laying out the storage of raw materials, considerable thought should be given to having the stock located as close to the flow of production as possible. This requires that pigments should be stored in one section readily available to the mixing floor; gums, oils, and thinners, near the varnish plant; and containers and cartons, easily accessible to the filling and packing departments.

Care should be taken in assigning warehouse space for raw materials to provide sufficient room for carrying a working stock between deliveries from suppliers and to accommodate shipments in either truckload or carload quantities. Also, arrangements should be made, preferably in a separate room, so that the can and carton storage area is kept free and clean of pigment dust particles. This will ensure clean containers for packaging the finished product.

Assembly of Batch Ingredients

It is generally standard practice to have a shop ticket for every batch of material being manufactured. This batch or formula card indicates the quantity of each dry material required in pounds and designates the amount of each vehicle in both pounds and gallons, thereby allowing for either a weighing system or a volumetric system for handling the liquids.

The batchmaker, under direction of his supervisor, then proceeds to assemble and weigh or measure out the various ingredients required. When the weighing operations are completed, the batch components are placed in such a position that they will be near the manufacturing unit which has been assigned for processing the product. This procedure permits final checking to ensure that all materials are at hand and that the quantity of each item is correct. No mixer should be loaded until this recheck has been made. This avoids costly and time-consuming errors.

For weighing pigments, a portable scale or a stationary platform scale, with dial indicators, is most convenient. Also, a small beam-type scale should be accessible for weighing small amounts up to 50 lb.

The method of handling vehicles varies with the measuring system employed: (*a*) When volume measurement is used, suitable metering devices should be provided and sufficient unit measures of various capacities must be available. Meters are usually hooked up so that the material can be metered and fed by pipe line directly to the point of operation or delivered to a portable tank. (*b*) When the system is on a weight basis, the portable or platform scales used for the weighing of pigments will suffice. In some instances a tank weighing scale, either supported by the floor or suspended, is installed and the liquids, after weighing, are either pumped or delivered by gravity to the operating equipment where they are required.

The assembling of the batch ingredients is very important, and the personnel selected for this work must be careful and accurate by nature and training.

Mixing

In the mixing of the dry pigments with the vehicles, many different types of mixers are used. The materials may be pre-mixed to a semi-paste consistency suitable for grinding on a roller or stone mill, or the mixing and grinding may be combined into one operation as in pebble and ball mills.

In preparing pastes for grinding on roller mills, the mixing action is accomplished in low vats or tanks which are equipped with heavy stirrers. Lead mixers, dough mixers, and portable change-can or pony mixers are ordinarily used for this purpose. In the mixing process, the pigments are brought together with a suitable quantity of the vehicle in the formula to produce a paste of proper grinding consistency. This mechanical action partially wets the dry pigments, but, at the same time, some agglomerates of semiwetted pigment are formed. Prolonged mixing will eventually break up these agglomerates, but the rubbing action of roller-mill grinding is faster and is employed for this reason.

For best results, the consistency of the grinding paste should be as heavy as possible in order to get the advantages of the internal shearing action which is set up when a very heavy mass is repeatedly pulled apart by the mixer blades. When all the pigments have been mixed with the minimum quantity of vehicle necessary to make a stiff paste, then more vehicle can be added to obtain the proper consistency for grinding.

Mixers should be located so that the pastes, when ready for grinding can flow by gravity to the grinding units.

Where the mixing and grinding are done in pebble or ball mills, loading ports should be arranged in the mixing room so that the material can be fed by gravity through the floor directly into these mills.

Adequate piping facilities may be provided to permit feeding the vehicles most commonly used from the metering or weighing devices directly to the mixing equipment.

Some provision for dust removal is desirable when dry pigments or powders are being handled. This can be accomplished by having exhaust fans so placed that the air is drawn over the mixing equipment and away from the operator and carried to the outside atmosphere, or by means of a direct-suction system which has openings mounted over each mixing unit so that the dust is directly exhausted therefrom. Properly designed respirators should be supplied for the workers to wear as an additional precaution.

The following equipment will take care of the mixing requirements for manufacturing units with a daily output of 2000 gallons:

> Four 125-gal mixing capacity lead-type mixers set up in pairs and each pair equipped with a 20 hp explosionproof motor. The discharge gates of the mixers should feed directly into a suitable chute or pipe arrangement leading to the 3-roller mills.
>
> One 60-gallon pony mixer for making batches which will be ground on the 5-roller mill. This unit should be equipped with a 7½-hp explosionproof motor. For most efficient handling of batches, at least six mixing containers and two portable platform trucks or dollies should be provided.
>
> Two properly located loading ports for the pebble and ball mills.

In order to prevent costly tie-ups which can occur due to unforeseen breakage, it is recommended that a spare set of paste-mixer sweeps, driving pinions, and gears be kept in reserve for emergency purposes.

The operator begins the mixing process by placing several gallons of the vehicle in the mixer and then starting the machine. Pigment is gradually added until a stiff consistency is reached, and then additional vehicle and pigment are added to maintain this stiff consistency until all the pigment has been mixed in. After allowing the heavy paste to mix for 10 to 15 min the rest of the vehicle required for proper grinding consistency is slowly fed in until all has been properly and uniformly mixed.

Grinding

When the various types of grinding equipment are being operated in a paint manufacturing plant, the degree to which the pigment is dispersed in the vehicle is entirely dependent on the type of protective coating being made.

Roller mills are generally equipped with hardened steel rollers which

are hollow to allow for internal water cooling. These rolls are usually mounted so that the rolls are all in the same horizontal plane, in a combination of horizontal and vertical planes, or at an angle. The theory of grinding is the same for all multi-roll mills. The rolls revolve at different speeds and in opposite directions. The mills are equipped with worm gear devices so that the rolls can be moved against or away from each other. When the rolls are brought together, a line of contact is established across the entire length of the roll. Since the rolls revolve at different speeds, the first roll being the slowest and each succeeding roll faster, a given surface area of one roll will slide past a greater amount of surface area of the next succeeding roll. Thus, a rubbing action takes place and the paste between any two rolls is sheared and smeared out to a thinner film on the next succeeding roll. This action brings about the final dispersion. The closer the rolls are set, the greater will be the degree of dispersion. The roller mills are equipped with a feeding control device usually called regulator guide blades, or hopper, which keep the material in place and prevent the paste from running over the edges of the rolls. The ground paste is taken off the last roll by means of a scraper knife mounted in the apron plate which controls and directs the flow of the ground paste into a suitable collecting device, such as a portable change can, or into a pumping unit which pumps it directly to the thinning tanks.

In operating roller mills, the operators should be instructed to apply pressure evenly on both ends of the rolls in order to get proper and efficient grinding, and also to prolong the life of the dressing on the rolls. Periodically, the rolls should be checked to see that they are true and that uniform contact is being maintained between the touching roll surfaces.

All roller mills should be equipped with instantaneous stopping devices so that, if any foreign material should accidentally get into the mills, they can be stopped before any damage is done to the rolls. Proper safety guards are usually installed to prevent an operator from getting his hands caught between the rolls.

The rolls should be washed clean at the end of each day's operations and then left with a very thin film of a mixture of mineral spirits and raw linseed oil on them to prevent rusting. The cooling water should also be turned off at the end of each run so that the rolls do not become excessively chilled and thereby condense atmospheric moisture on the steel surfaces to cause rust formation.

The typical setting procedure for roller mill operation is to start the mill with the rolls open or apart. A check should be made to determine that the cooling water is circulating properly. Then paste is placed or

allowed to run on the feeding rolls, and the adjusting mechanism is tightened in order to bring the rolls together. The paste as it comes off the apron knife is tested to see if it is being ground to the standard degree of fineness. Further adjustments are then made until the grind is satisfactory by increasing the pressure on the rolls and also by controlling the rate at which the paste is being fed into the mill. Experienced operators soon get the feel of setting a mill so that they can start a machine and then very rapidly adjust it to produce the proper grind without very much additional regulating.

Pebble and steel ball mills depend on the movement of stone or porcelain pebbles and steel balls, respectively, within revolving cylinders for the dispersion of dry pigments in liquid vehicles. Pebble mills can be obtained with or without water jackets for cooling, although steel ball mills are always water jacketed. Each mill revolves at such a rate of speed that the pebbles or balls are carried up on the side of the cylinder by centrifugal action, but only at a speed that enables the force of gravity just to overcome this centrifugal force and allow the pebbles to fall and cascade over each other. Thus the material being ground in this type of mill is subjected to crushing by the impact of pebbles on pebbles, and by the rubbing of pebbles against each other and the lining of the cylinder. The process is continued as long as is necessary to obtain the desired degree of dispersion. Other factors which affect the operation of these mills are:

Relation between Pebble and Material Charge. The relation between pebble and material charge varies, depending on the material being processed. Mills are usually charged from 40 to 50 per cent of the cylinder capacity with pebbles.

Mills containing a low ball or pebble charge are harder to clean than when they are half full because paste tends to adhere to the ends of the mill near the hub and is difficult to remove when the charge is low. When the mill is half filled, the grinding medium is continually sweeping this area clean.

To obtain the best possible grind in the shortest possible time, a ball or pebble mill should be loaded so that the paste to be ground will slightly more than cover the grinding medium. This gives the highest ratio of medium to paste. Assuming that a mill is half filled with medium, the paste volume will be only 20 to 25 per cent of the volume of the empty cylinder, since about 40 per cent of the apparent volume occupied by the balls or pebbles is void.

There are practical considerations beyond getting the best grind in the shortest time. One is that a day has 24 hours, about four of which may be required to load and unload a mill. This leaves 20 hours for

grinding, and the paste charge may be increased above the theoretically ideal volume to utilize that entire time. If the grind must run more than one day, it should run for even days plus the original 20-hour interval.

Another practical limitation is the total quantity of an item to be made. If the ideal load would result in a 125-gal batch but 150 gal had been ordered, the course to pursue would be quite clear. Also, an adjustment in the size of batches is frequently necessary to fit some specified mixer in which further processing is planned.

The grinding paste charge is then varied, depending on the ease with which the material disperses. To operate efficiently, this loading charge must be carefully determined for each type of product being processed.

Consistency of Material Processed. Usually the consistency resembles thick soup or heavy cream. The consistency cannot be heavier than that which will allow the pebbles to move freely in the mass.

The correct paste consistency is difficult to determine because it depends on ball size, diameter of mill, speed of mill, and density of the paste.

The paste should be of sufficient consistency so that the balls are carried fairly well up the side and then roll down over the top of the retained mass. If they are carried so high that they fall from the top of the mill and bounce against the mass, they may shatter by impact, resulting in contamination. This is particularly a factor with pebble mills. Too thin a paste promotes sliding of the mass against the shell, resulting in excessive wear of lining and grinding medium, as well as discoloration by abraded material.

Pebble or Ball Size. The size and density of the grinding media should be great enough to prevent them from floating in the material and to obtain the maximum amount of grinding surfaces.

The optimum size of balls is about ⅝ to ¾ in., as recommended by manufacturers. As the balls of smaller diameter are used the number of contacts increase greatly. One-inch balls have approximately 38 contacts per pound, whereas ⅝-in. balls have 144. However, four factors limit the extent to which one can go in this direction:

1. Smaller balls will tend to "float" or rise in the paste as the mill rotates. This can be overcome by lowering the pigment concentration to reduce the paste viscosity. But a point is reached where the reduced grinding time is overbalanced by the smaller quantity of pigment ground.

2. Smaller balls or pebbles make a mill harder to discharge because of smaller channels in the mass through which the paste can flow.

3. Balls of too small a size will not be held back by the screen or grate in the discharge opening of the mill. These can cause serious trouble if they lodge in valves or in the pumping mechanism.

4. Small pebbles, because of the relative size, are less effective in breaking up large agglomerates of paste or pigment and may tend to promote formation of pigment balls in a mill.

In operating pebble or ball mills the pebble charge should be checked periodically to ascertain if the correct volume of grinding medium is present and then to adjust for wear of the pebbles. At least once a year the pebble charge should be unloaded from the mill and the pebbles or balls culled and screened to remove any that are broken or defective and to replace those that are badly worn and undersized. A screen of appropriate mesh can be constructed for that purpose.

The operating procedure for pebble-mill grinding involves placing all the pigments and a predetermined portion of the vehicle in the mill, after which the loading hatch cover is bolted down.

Sufficient vehicle should be put into the mill to come just to the top of the ball level. If pigment is loaded first, it prevents liquids from penetrating through the pebble voids and makes the mill more difficult to load, an extra session of spinning the mill usually being required. There is evidence of an overall advantage in loading certain pigments, plus sufficient vehicle, into a mill and grinding several hours, after which time the remainder of the pigment and vehicle is added and the grinding continued.

Ball formation in a mill constitutes an annoying problem. In this situation a mass of pigment, balls or pebbles and some vehicle, form a large round ball that will roll in a mill for hours and not be broken. It is definitely promoted by too high a paste level, too low a pebble level, and too thin a paste. If the paste level is too high or the quantity of pebbles too low, there is a definite tendency for a ball to form and roll on top of the mass, never being drawn into the grinding area. Increasing the consistency of a too thin paste will frequently eliminate ball formation because the more viscous paste tends to pull the round mass down below the surface of the grinding medium where all the dispersing action takes place.

After loading, the mill is then started revolving and the loading and discharge closures are checked to be sure that they are tight and do not leak. The mill is then allowed to run either a previously determined number of hours or revolutions. At the end of this time a sample of paste is checked for fineness of grind, and, if it is not satisfactory, the mill can be operated longer until the correct degree of dispersion is ob-

tained. The mill is then stopped, and enough of the remaining vehicle is added to produce a consistency suitable for discharging the ground paste from the mill. The mill is closed again, rotated for 15 or 30 minutes to ensure uniform mixing, and then the thin slurry of paste is ready to be discharged either by gravity or by means of a pumping device. When the charge has been removed, a portion of the thinning vehicle is put in the mill which is then closed and rotated again. This serves to wash out the mill, and the remainder of the ground paste is thereby added to the batch in process.

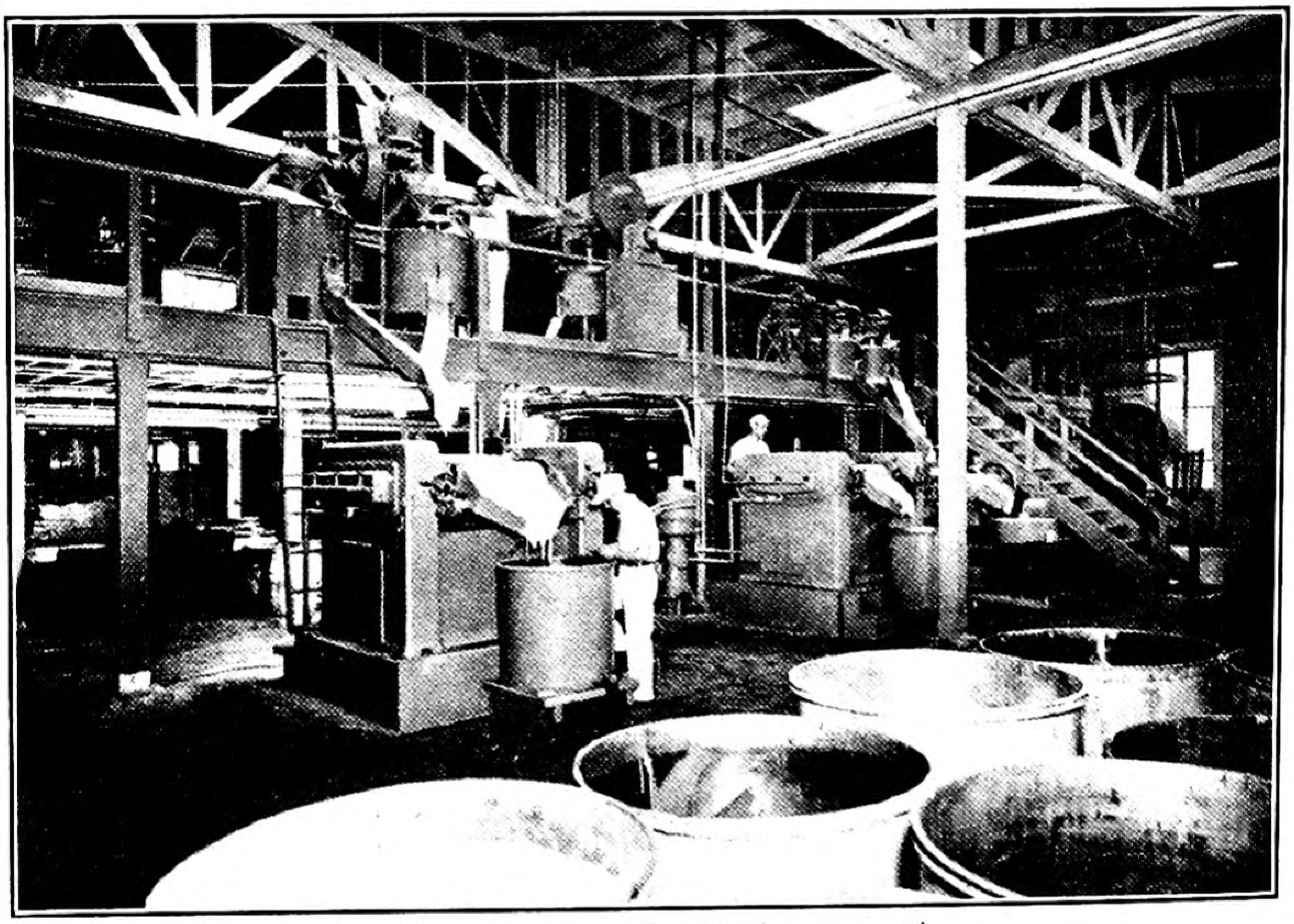


FIG. 47. Mixing and grinding operations.

The grinding department should be equipped with several standard-type grinding gauges for testing the degree of fineness of grind. The mill operators should be thoroughly instructed in setting their machines to produce the grind required for any product. The ground paste from roller mills should be checked repeatedly during the processing of the batch. Should there be any variation due to the mechanical functioning of the mills this can then be immediately corrected so that the quality of each product is maintained.

For the purpose of this discussion the following grinding equipment is recommended for a daily production of 2000 gallons:

Two 13- x 32-in. 3-roller high-speed mills, each equipped with a 25-hp explosionproof motor.

One 13- x 32-in. 5-roller mill, equipped with a 20-hp explosionproof motor.

One 4- x 5-ft Buhrstone lined pebble mill, equipped with a 10-hp explosionproof motor.

One $3\frac{1}{2}$- x 4-ft chrome manganese steel ball mill, equipped with a 10-hp explosionproof motor.

Thinning

The thinning operation involves the addition of that portion of the vehicle in any given paint formulation which is not required for the grinding process and thus completes the product for tinting or filling as the case may be.

This operation can be accomplished in several ways, and the transfer of the base products from the grinding mills to the tanks for thinning purposes varies with the plant layout. Often the ground paste is discharged directly from the roller mills or pebble mills into the thinning tanks which may be portable or stationary. Other schemes for handling involve arrangements to pump the paste away from the roller mills, or out of the pebble mills into the thinning tanks.

The type and size of the tank will depend on the amount of paint to be thinned at any one time. Thinning tanks should be equipped with an efficient agitator device to mix the ground paste and vehicle thoroughly and uniformly. Usual stirrer speeds range from 60 rpm to 100 rpm. Tanks for thinning small batches up to 125 gal are usually portable, such as the change-can type.

The vehicle for the thinning operation should either be metered or weighed into the tank and added slowly while the paste or semipaste is being agitated. If the vehicle is metered, the discharge end of the meter should be connected by means of adequate piping directly to the thinning tanks. If the vehicle is weighed, it is convenient to have the weighing tank located so that the material can flow by gravity or be pumped into the tank.

Stationary thinning tanks should be equipped with individual motor-driven agitators so that in case of breakdown no more than one tank is idle while repairs are being made.

Portable change-can tanks are placed under a change-can mixer unit and then the stirring arm is lowered into the tank either by means of a hand-operated mechanical device or by hydraulic control.

A definite program for keeping the thinning tanks clean should be established. This will avoid contamination with non-compatible materials and also prevent excess accumulation of skins and dirt which must be removed by screening later on. The portable change cans should be

washed clean with thinners after each batch. The stationary tanks should be washed out after each run of colors and periodically scraped clean down to the metal.

For a manufacturing unit of 2000-gal daily capacity the following tankage will be required to allow time for proper testing of batches and to maintain continuous flow of production:

Six 300-gal stationary tanks, equipped with individual 3- to 5-hp explosionproof agitator units.

Twenty portable change-can tanks of 125-gal mixing capacity.

Two change-can mixer units, equipped with 3-hp explosionproof motors.

Tinting

The public appreciation of the possibilities of color for decorative purposes has accounted for the sale of a tremendous volume of paint coatings in a wide variety of tints. In order to satisfy this demand, the tinting operation has become an important step in the manufacturing schedule and must be given special attention.

Even the bluing of white products is customary which not only improves the appearance but also increases the hiding power. Other shades are made either by adding tinting color to white bases or by adjusting the solid color bases which have been formulated as complete products with tinting color to match the standards.

Tinting color bases are prepared as far as possible from CP colors in order to obtain the maximum effect from adding the minimum amount of material to the batch. The colors should be well ground in vehicles which are compatible with the base products, and the consistency of each tinting paste should be thin enough to work into the batch easily with agitation.

Color matching is an art which can be developed through experience, providing that the eye of the operator responds correctly to various colors and he has the ability to judge differences and can determine the amount and kind of color to produce desired effects.

Suitable lighting conditions are essential to good color matching, and an abundance of north daylight or, if the light is artificial, an approximate substitute is desirable.

The accurate tinting of batches can take a great deal of time. First, as close a match as is possible is obtained by comparison of the wet films of the tinted batch, the previous batch, and the wet or dry films of the standard. Satisfactory uniformity can generally be secured if a combination of wet color standards and dry color standards are used. Be-

cause of the changes which take place on drying, final approval should be deferred until the dried films of both batch and the standard can be observed.

Excessive retinting to obtain the correct shade may be avoided if the amount of tinting colors added to previous batches is known and similar quantities are added to the batch in process.

The principles involved in the use of color for tinting purposes have been explained thoroughly by H. L. Beakes under the title of *Guide for the Tinting of Paints*, which is republished herewith by permission.

White, neutral grays and blacks are not colors, and differ only in their ability to reflect light. Pure white reflects the maximum amount, hence has the value of 100%. Black reflects none, grays are of intermediate percentage. Color, being distinct from gray, possesses two other properties, first a name: red, blue, green, etc., second a designation describing its freedom from grayness or how clean the color appears.

The Munsell system* is recognized in Government specifications, hence their notation and nomenclature are used here. They are:

Value: the percentage of light reflected. Its brightness, as in light, medium or dark colors.
Chroma: its degree of freedom from grayness, its saturation, as in clean or dirty colors.
Hue: the name of a color, as yellow, purple, etc.

These three properties are measurable, hence color has three dimensions and may be visualized as a color-solid or sphere; black at the south pole, white at the north pole. The axis then represents all intermediate grays between black and white.

Munsell recognizes five primary hues: red, yellow, green, blue, and purple and places these equidistant on the circumference of the sphere. Midway between each are intermediate hues such as yellow-red, green-yellow, blue-green, purple-blue and red-purple. Other intermediate hues are given names or notations.

A hue is represented as extending from the axis to the circumference, which is a variation in chroma. Hues that appear grayer lie closer to the axis. Cleaner or less gray hues are nearer the circumference. Hues that are directly opposite each other about the neutral axis, or 180 degrees apart, are complementary and when mixed in the proper proportions will produce neutral gray. The complementary color of red is not green, but blue-green; that of green is red-purple. The popular red and green Christmas colors are not complementary.

Pigments, particularly the chemical colors, appear as separate families of related colors such as chrome yellows, organic reds, iron blues, and chrome greens. Each family is related by similarity of composition but offers variation in hue. This variation will be towards the adjacent hue to one side or the other. For yellows it will be towards

* *Munsell Book of Color.*

the green or the red, for greens towards the blue or the yellow, for blues towards the green or the red (purple).

For this reason chrome yellows range from the primrose yellow, which is to the green side of yellow, to the dark orange chromes which are to the red side of yellow. Chrome greens vary from the one type which has a mass color on the blue side of green to another type which has a mass color on the yellow side. Iron blues towards the green side are Chinese blues, those to the opposite side are the redder Prussian blues. In the organic group, para reds range from the light para, with its yellow undertone, to the dark para, with the well-known blue undertone (more properly purple).

Mixing widely separated pigments introduces gray into the batch. If the pigments are complementary and their coloring power is equal, the mix will be neutral gray. If one pigment is dominant, the result is a gray variation of that hue. The less widely the pigments are separated, the less gray will be introduced. If a medium chrome yellow is to be matched, no mixture of primrose yellow and dark orange chrome will be satisfactory as shown by Plate Number 1. Primrose yellow and orange chrome are bright clean colors, each a satisfactory representative of its hue. The only objection is that for this purpose the hues they represent are too widely separated. Primrose yellow is greenish, orange chrome is reddish. Red and green are complementary and produce gray, hence the mixture is grayer or dirtier than the medium chrome yellow produced by the pigment manufacturer.

If the pigments to be mixed had been located in the color sphere nearer medium yellow, then less gray would have been introduced. Light chrome yellow and light orange chrome would be closer, but the best match from mixed pigments is made by mixing together a medium yellow slightly yellower and one slightly redder than the medium yellow in question.

Similar to the above is the difficulty in matching a given red. The paint manufacturer usually carries two para reds, a light para which is yellowish and a dark para which is bluish. Mixtures of these two produce a series of reds adequate for most purposes as they will match the special reds of other paint manufacturers who produce their reds similarly. On the other hand, no combination of these two paras will match, for example, the medium para made as such by the pigment manufacturer. The yellow of the light para mixed with the blue of the dark para produces green which is complementary to the red and therefore makes the red grayer or dirtier than desired. This is the best match to medium red that the tinter can make by combining a light and dark shade. He has obtained the correct hue, but the resulting color is too gray.

Failure to recognize this leads only to the introduction of other yellower reds and other bluer reds which increases the gray content of the mix so that the batch gets dirtier and dirtier. This type of pigmentation is made use of in the industrial field as a means of holding business where standards offering difficulties in matching are resorted to. Similarly machinery grays may be advantageously

tinted with transparent black such as asphaltum rather than opaque pigment black, to make matching difficult.

Plate Number 2 illustrates the series of colors obtained by mixing toluidine red and chrome green. The intermediate colors between the red and the green are degraded colors. They result from the quantity of red and green in the mix that balances in coloring power to produce gray. The final color is the result of this gray plus the unneutralized color.

Chrome green itself is a mixture of yellow and blue, hence the same series of colors could be produced by combining the red with yellow and blue. In the same manner, the second member of the series on Plate Number 2 can be made by combining the red with any of the colors beyond the second, such as the third, fourth, etc. Likewise any member of the series may be made by combining any member before it with any member following it. If the problem is to produce the third member of the series, it is not necessary to start with so brilliant a red as toluidine, since a red no better than the second member would be equally satisfactory. For this reason, the earth colors and the iron oxides are satisfactory starting points for many shades.

Many hues shown on color cards are not those obtained from pure pigments or their tints, but from mixtures of two or more pigments. These are degraded colors, sometimes called secondary colors as they contain fair quantities of gray. Such colors are the type of coral, fawn, cream, buff, sage, jade, bottle green, bronze green. Many of the primary hues have well-recognized degraded colors. For example:

Primary	*Common Name of Degraded Color*	
Hue	Dark Hue	Light Hue
Yellow	Olive	
Orange or yellow-red	Brown	Tan
Red or red towards purple	Maroon	Pink
Purple-blue	Navy blue	
Purple	Plum	Orchid
Green	Brewster green	

These common names do not apply to a particular color, but to a region of color in the color solid. This region varies in three dimensions (1) percentage of light reflected (2) gray content (3) hue, which extends to either side to the nearest adjacent primary. A seed located inside an apple may be pierced with a skewer from many directions. In the same manner a color located inside the color sphere may be matched with many pigment combinations.

While the method of obtaining these degraded colors applies to any of them equally well, it is more easily illustrated with browns, since the field is so large and the color is so common. Brown is a mixture of orange and dark gray. If the gray content is light gray, the resulting color is tan. Browns are dark to medium in light reflection, tans from medium to light. Since browns are oranges in hue, the primary on one side is yellow, on the other is red; hence there are yellow browns and red browns.

The saturation, or chroma, is adjusted depending on whether there is a lot of gray and a little orange, or less gray and more orange. To produce brown, gray must be introduced into the mix.

Plate Number 3 illustrates possible methods of accomplishing this. Black itself may be used to introduce gray, or gray may be formed by adding blue which is the complementary color to orange. Iron blues may be on the green side (blue plus yellow), as in Chinese blue, or on the red side as in Prussian blue. Results will depend upon the blue used.

Blacks may show a blue content as in lampblack, or a red content as in carbon black. This affects the results. Oranges themselves vary from light orange which has considerable yellow and some red, to the dark orange with much less yellow and a greater red content. This causes variation in results.

The above pigments have just been described as combinations of blue, yellow, and red. For these the symbols B, Y, and R may be used. The study of browns becomes an exercise in following the combination of these symbols:

Orange is Y + R.
Chinese blue is B + Y.
Prussian blue is B + R.
Lampblack is black + B.
Carbon black is black + R.

Plate Number 3 shows oranges tinted to various depths with blues and blacks. Rows 1 to 3 inclusive show the variation in color due to the type of orange used, whether light, medium, or dark. These tints are made with Chinese blue. Rows 3 to 6 inclusive show the variation in color due to the type of tinting color used with the same dark orange.

It will be observed that for the same tinting material, the variation in color of the mixes follows the variation in color observed in the orange chromes. Light orange chrome is yellower and less red than the medium, while the dark orange chrome is the reddest of the three. The same is true of the browns produced with the Chinese blue, as illustrated in the column 3rd Tint.

On Plate Number 3 in rows 3, 4, 5, and 6 carbon black produces the reddest brown, the lampblack next, then Prussian blue with Chinese blue the yellowest of the four. The explanation of these variations is most easily followed by observing what happens to the red content of the pigment combinations.

Orange with carbon black may be represented:

$$\frac{\text{Orange}}{\text{Y} + \text{R}} + \frac{\text{Carbon black}}{\text{Black} + \text{R}} = \frac{\text{Brown}}{\text{Y} + \text{R} + \text{Black}}$$

The Y + R of orange is unchanged. Carbon black has added black to lower the light reflection and a little additional red. The resulting brown is the reddest of the combinations illustrated regardless of how dark the final brown may be.

Orange with lampblack is:

Plate Number 1

Mixes of Primrose Yellow and Orange Chrome
Compared with Medium Chrome Yellow

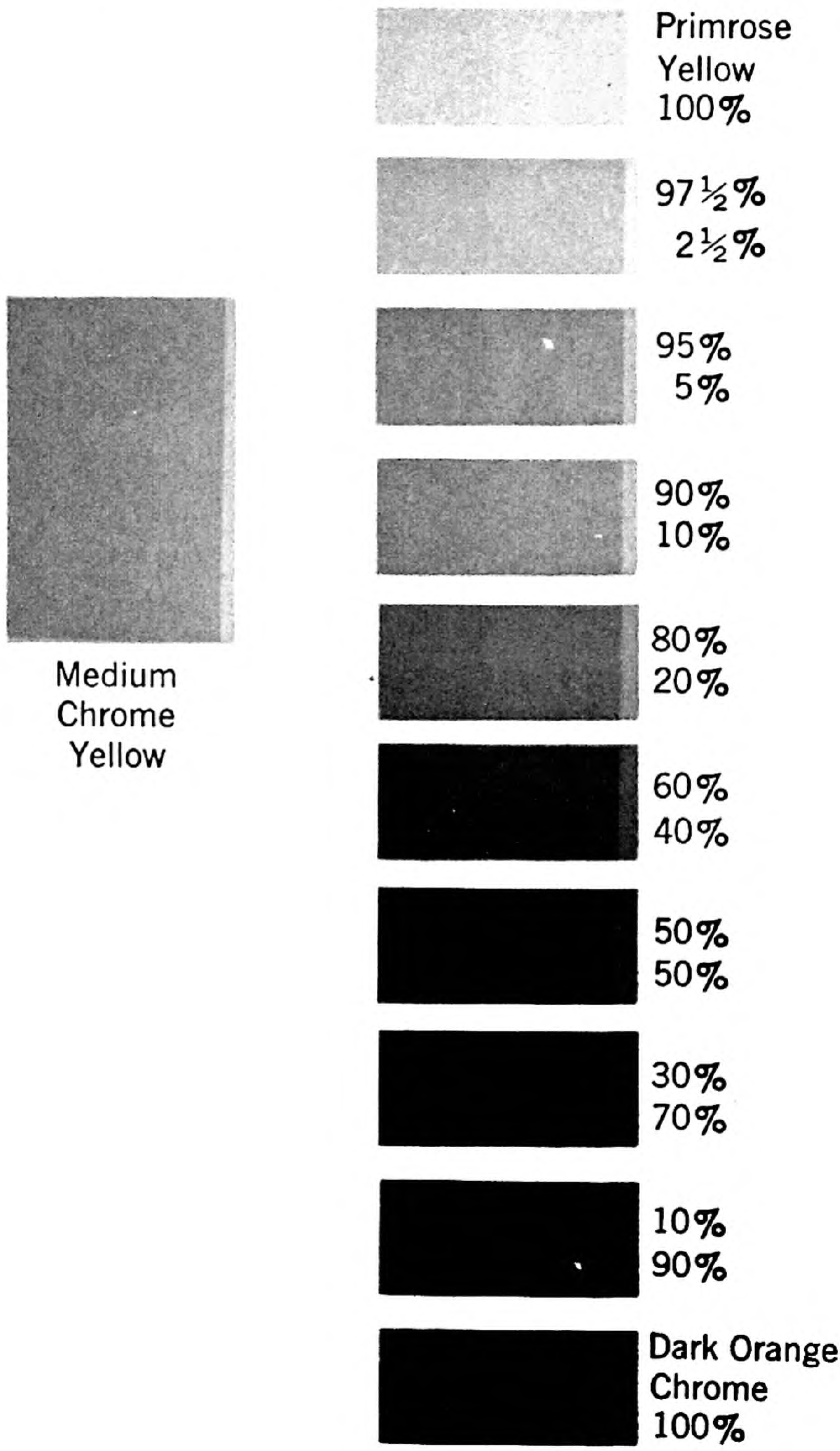
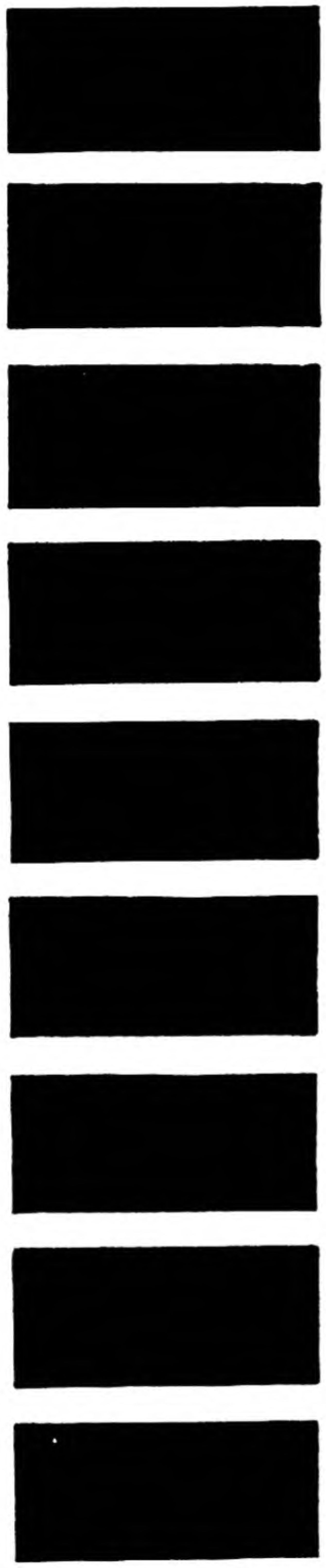


Plate Number 2

Red and Green with Intermediate Mixes



Toluidine
Red
100%

97½%
2½%

90%
10%

70%
30%

50%
50%

32½%
67½%

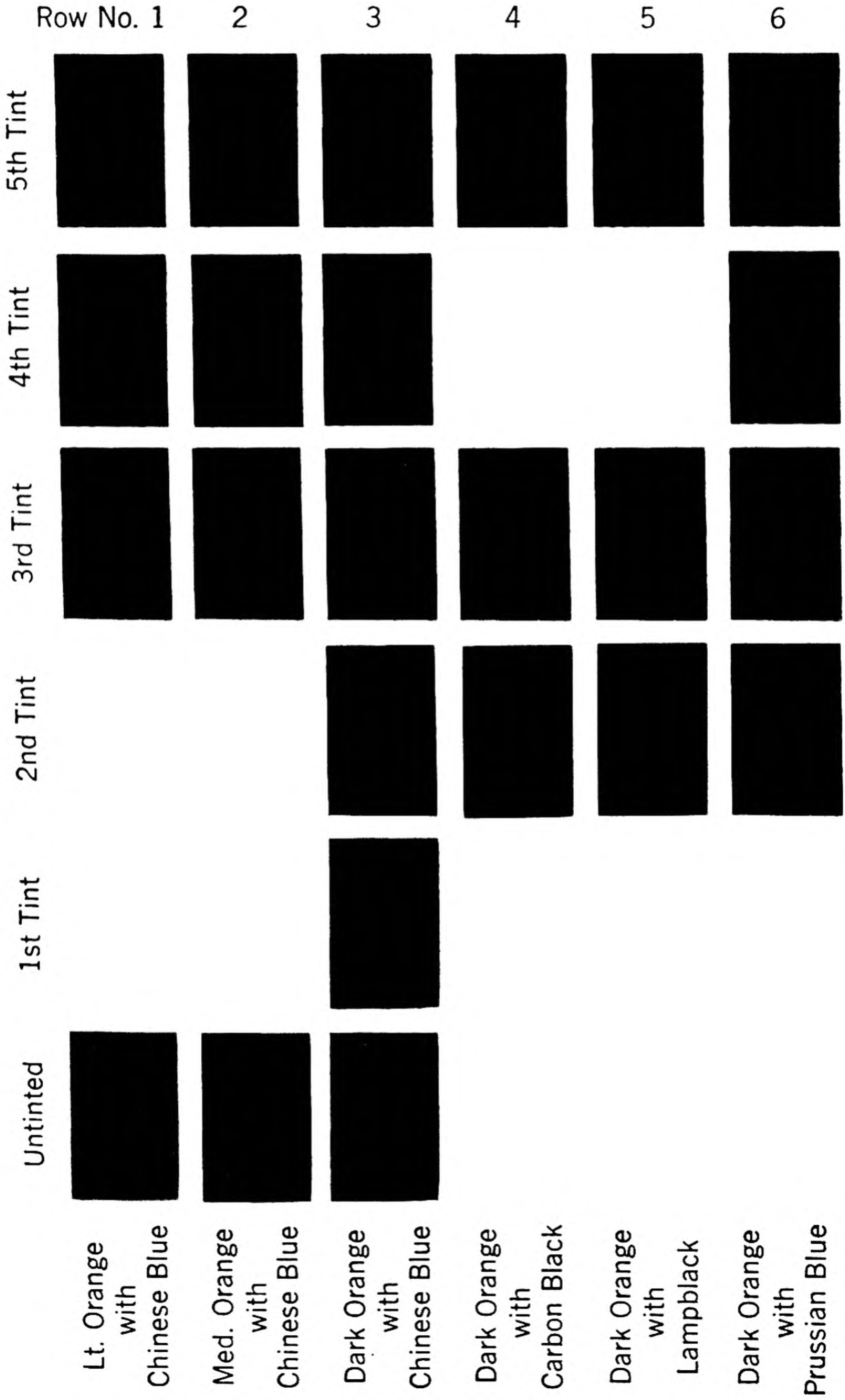
20%
80%

10%
90%

Chrome
Green
100%

Plate Number 3

Oranges Mixed with Blues and Blacks



$$\frac{\text{Orange}}{Y + R} + \frac{\text{Lampblack}}{\text{Black} + B} = \frac{\text{Gray}}{BY + R} + \frac{\text{Brown}}{YR + \text{Black}}$$

Here the small blue content of the lampblack with some of the yellow content of the orange forms blue-green, complementary to the red content of the orange. This combination produces gray, hence for equal light reflection the resulting brown will not appear as red as in the case with carbon black. Carbon black added red, lampblack subtracted color.

Orange with Prussian blue is written:

$$\frac{\text{Orange}}{Y + R} + \frac{\text{Prussian blue}}{B + R} = \frac{\text{Brown}}{BY + R + YR}$$

The blue in combination with some of the yellow content of the orange again forms blue-green. This time there is more blue-green formed than in the case with lampblack; hence more red will be neutralized than in the previous illustrations. The blue here contributes a small amount of red. The final brown again shows less red and more yellow than the previous mixes.

Orange with Chinese blue is similar to the Prussian blue except that the blue is written $B + Y$; hence the total red content is less to begin with, while yellow is increased. After the production of gray, the resulting brown will contain less red and more yellow than was the case with Prussian blue.

Other orange chromes merely alter the proportion of Y to R in the mix. The lighter the orange, the more Y and the less R, resulting in browns that appear yellower because there is less total red in the mix.

As a first corollary to the above, it will be noted that the only problem is the manner of introducing gray into the orange mix. Obviously there are many sources of gray. Plate Number 2 illustrates one such source, the 50–50 mix of red and green. This combination will degrade the orange equally well. Also the Plate Number 2 shows the 70–30 mix of red and green as a very red brown. Since red is in excess, the YR balance for orange can be restored by the addition of yellow.

As a second corollary, the principle illustrated in Plate Number 1 applies as regards the source of orange. Instead of a brilliant orange, a mixture of a yellower and of a bluer pigment produces a less bright or a degraded orange which may even approach the 1st Tint shown on Plate number 3.

This procedure of increasing the yellow and reducing the red as by the use of lighter and lighter oranges, as illustrated on Plate 3, may be continued on into the yellows where the browns are sufficiently yellow to be classified as olives. The Army olive drab is a degraded yellow of low light reflection. The customary formulation of ferrite yellow lampblack, and venetian red may be written:

$$\frac{\text{Ferrite}}{\text{Gray} + Y} + \frac{\text{Lampblack}}{\text{Black} + B} + \frac{\text{Venetian}}{\text{Gray} + R} = \frac{\text{Olive drab}}{BY + R + \text{Gray} + Y}$$

The blue of lampblack combines with some of the yellow of ferrite and neutralizes the red of venetian red to produce gray. The excess yellow of ferrite leaves the gray on the yellow side and of low light reflection. It will be observed that the final product contains B, Y, and R which have canceled out to produce gray with Y in excess.

Experience in making camouflage colors showed that the use of ordinary blacks and iron blues used in olive drab mixes produced coatings of too low infrared reflection. It was necessary to produce the color from pigments of satisfactory reflection. Obviously the B, Y, and R above can be used in any combination and any quantity so that the final B and R are canceled out with sufficient Y to produce sufficient gray with enough Y left in excess. Hence B may be combined with some Y as in chromium oxide and in hydrated chromium oxide. R may be combined with B as in Indian red and maroons; Y and R as in oranges; B with R as in phthalocyanine blue and ultramarine blue.

Consequently infrared camouflage formulae became numerous as

1—orange chrome, ferrite lemon, phthalocyanine blue.
2—hydrated chromium oxide, molybdate orange, Indian red, medium yellow.
3—chromium oxide, molybdate orange, Indian red, ultramarine blue.
4—black antimony sulfide, ferrite lemon.
5—chromium oxide, orange chrome, black antimony sulfide.
6—chromium oxide, medium chrome yellow, maroon.

All these produce the required olive drab, and illustrate the possible sources of B, Y, and R which when mixed neutralize to produce the necessary gray leaving Y in excess. The final choice of pigmentation is governed by the price of hiding power of the desired color, bleeding, ease of grinding, color permanence and such pigment characteristics. While there are many ways of matching most colors, the final choice must be industrially practical.

In matching a given standard hue, consideration must be given to its dominant characteristic. This may be its high brightness, its cleanliness (freedom from grayness) or both. Each of these is rapidly lost in tinting. Once the end-point has been passed, large quantities of the original clean or bright batch are required to off-set a slight error.

Exceedingly small amounts of iron blue or of black in a batch of clean yellow or in a batch of refrigerator white make a tremendous change. This is because colored pigments act as light filters absorbing some of the light. Light thus absorbed is not reflected, hence when color is added to white it is not as bright, furthermore the change is not directly proportional to the amount of color added.

A little black added to white makes a big brightness change. The same amount added to medium gray by comparison gives only a slight change. A batch of yellow tint and one of blue tint of equal light reflection when mixed have lower light reflection than the

batches from which the mix was made, and the mixture has less saturation (is grayer) than either original batch.

Color matching is an appreciation of the location of the standard color in the color solid with reference to the color of the batch. To move from the batch color to the standard color may involve a change in one or more of the following: (1) brightness (2) grayness (3) hue. This is accomplished by the addition of pigments having an excess of the required characteristic thus overcoming the deficiency. If the difference is small it is called tinting; if the difference is such that it involved assembling of pigments to produce the required color characteristics, it is color formulation.

Filling

In the filling operation paint must be strained first before it is ready to be put into the containers specified.

The straining of paints can be simplied if care is exercised during the course of manufacture to eliminate the many sources of contamination with grit, skins, and foreign material. Various grades of fabrics, such as cheesecloth, muslin, silk bolting cloth, and felt as well as stationary and vibrating metal screens are used for straining. These screens can be equipped with wire cloth of various-sized mesh and made of copper, bronze, Monel metal, or stainless steel. The mesh of cloth which is generally satisfactory for different types of material is listed as follows:

Flat and exterior house paints	20– 40 mesh
Interior gloss paints	60– 80 mesh
Interior enamels	100–120 mesh
Industrial enamels	140–200 mesh

In handling certain high-grade finishes, ordinary screening is not good enough and a variable-speed centrifugal clarifier may be necessary to remove objectionable material.

After straining, the paint is fed to a filling station. These filling stations are usually small tanks of 50- to 150-gal capacity out of which the paint can be hand filled or connected directly to a filling machine by means of flexible metal hose.

Depending on the size and number of containers to be filled at any one time, it must be decided whether hand-filling or machine-filling will be employed. Filling equipment has been improved to such an extent that it can be economically used in the average paint plant. Most machines are easily adjustable for filling $\frac{1}{32}$-gal to 1-gal containers at the rate of 12 to 18 one-gal cans per minute or 25 to 35 smaller-size cans per minute. The filling is controlled so that each container, when directly under the filling spout, is correctly filled and then the container is carried on a conveyor belt to a point where the lid is automatically put

on and the can sealed. The closed units can then be directly delivered to the labeling machine by suitable conveying equipment. Five-gallon kits may be filled by weight or volume; drums are usually filled by weight, and the gallonage is calculated by dividing the net weight by the weight per gallon for the material.

The filling operation can be arranged so that a minimum amount of time is necessary for cleaning the equipment by scheduling the sequence of batches so that the order of filling can follow from white and very light tints to the darker colors. By this method, all that is necessary is to flush out the machine with thinners after each batch, an operation which will take just a few minutes. Thorough cleaning, such as is required at the end of the day or when changing to an entirely different color, usually takes one-half to one hour. Machine filling is not considered economical when the number and size of containers is fewer than 100 gallons, 400 quarts, or 800 smaller-size units.

When cans are filled by hand, a suitable closing device should be provided so that the covers or lids can be sealed by mechanical means.

In order to identify the contents of each can of filled material, the lids should be embossed with a suitable identifying code. This can be accomplished by means of a cover-stamping machine which has changeable dies for numerals and letters and is power operated.

Since automatic filling is good economy in most paint and varnish plants, it is desirable to have equipment manufacturers supply engineering service for properly planning the most efficient installation.

The following equipment is essential for the filling department of a unit operating at 2000-gal daily capacity:

Four filling station tanks which will contain 100 gal each.
Two vibrating strainer units and three sets of 40-mesh, 80-mesh, 100-mesh, and 150-mesh screens.
One portable scale for weighing drums and 5-gal cans.
One cover-stamping machine.

Labeling

The choice of equipment for economic labeling will depend on the volume of material and the sizes of containers to be labeled. Labeling machines are available which can be adjusted to label all sizes from $\frac{1}{32}$-gal up to the 1-gal size.

The labeling operation should follow the filling operation at once in order to avoid intermediate handling. A conveyor is usually installed between the can-closing device and the labeling station, on which the cans are carried directly to the labeling machine. To eliminate han-

dling, a twister should be provided to turn the cans from a vertical to a horizontal position at the point where the cans enter the labeling machine. The labeled cans are then taken from the end of the machine and put on a conveyor leading to the packing station. Cleaner labeled packages result if the labeling operation is done after the cans have been filled. During cold-weather months, filled cans should not be allowed to go below room temperature in order to prevent the pick-up glue from setting too fast for the label to adhere to the tin.

A stencil-cutting machine is desirable for marking drums and 5-gal cans. Labels are generally applied by hand to 5-gal containers and larger sizes.

Where no cover-embossing machine is available for coding the can covers, a perforating machine should be provided to perforate the batch number on the label for future identification purposes or a rubber stamp may be used.

It is very important that the labels of the correct size and proper quantity be on hand when a batch is ready to be filled and labeled. This can be controlled by having a label requisition made out for each batch card which specifies the quantity and sizes. The requisition goes to the label stockroom which should be controlled by the department foremen. When the requisition is received, the quantity of labels in the various sizes required can be assembled and kept together under the batch number. Then, when the batch is ready for labeling, the labels will be on hand and delays will be avoided. If the labels are not in stock at the time the requisition comes through, then the production-planning department can be advised and the manufacture of the item can be deferred until the labels are on hand. This will prevent filled cans, for which no labels are available, from occupying valuable space which can be put to better use.

As a matter of operating efficiency, the label stock should be maintained on a minimum and maximum basis. Data on requirements and inventory should be compiled and kept up to date in order that no wastage of labels may occur because of overstocking or obsolescence. It is generally considered good practice to keep a 6-months supply of labels on hand. Some plants prefer to stock only blank labels of the various sizes and to imprint them as required.

For the output under discussion the following recommendations are in order:

One labeling machine capable of handling $\frac{1}{32}$-gal up to 1-gal can.
One stencil-cutting machine.

Packing

After the cans pass through the labeling machine, they should be put on a conveyor to move them to the packing station. They are then packed into cartons of the proper style and size and sealed. The metal bails of 1-gal cans should be affixed to the ears of the can before they are packed into the cartons.

The dividing partitions which are used in the 1-gal and 1-qt cartons should be stacked where it is convenient for the packer to insert them in the cartons just before the cans are placed inside.

It is standard practice to stencil the cartons with the name of the product, the batch number, and any other data which may be desired. This can be done before packing the cartons and while they are still flat.

Several methods are employed for sealing cartons as follows:

The top and bottom can be glued by hand.

The cartons can have the bottom stitched shut with a wire-stitching machine and then, after the cans have been put into the carton, the top cover flaps can be glued by hand.

Closing with a carton-sealing machine. The carton, after it has been folded into shape and the cans packed in it, is fed by means of a conveyor into the carton-sealing machine unit. As the carton passes through the machine, the top and bottom flaps are folded back, closing the carton. From the gluing unit the carton passes into a compression unit where the carton travels along a conveyor while it is under pressure long enough for the glue to set.

After the cartons have been sealed, they can be stacked on platform skids for transportation to finished-stock storage, or a conveyor system can be so installed that the sealed cartons are carried directly to a centrally located distributing station in the finished-stock storage section. In plants where the total production is only 2000 gal per day, it would not be economical to use a sealing machine. Therefore, a wire-stitching machine is recommended.

In the interest of an economical procedure for filling, labeling, and packing, these operations should be laid out so that one immediately follows the other, and by means of conveyors the labor of handling is reduced to the minimum. The experience of manufacturers of filling and labeling machines can be very helpful in obtaining the most efficient layout to meet specific requirements for the handling of finished goods.

Storage

After the filled cartons have been transferred by conveyor, trucks, or pallets to the warehouse, they should be placed in bins which have been

assigned to each product. Usually, the smallest sizes are stored in the highest bins and the largest sizes in the lowest bins or directly on the floor to conserve space by taking full advantage of the headroom. An extra bin for each product or allied group of products is recommended for holding any loose cans left over after the various-size cartons have been packed. When orders for units smaller than full cartons are received, these extra cans can be used to fill orders. Later when cartons have to be broken to fill these small orders, the extra cans may be placed in the catch-all bins.

A plant with a capacity of 2000 gals per day should have warehousing capacity for 40,000 to 80,000 gal, depending on the turnover for the different sizes and types of products being manufactured. The estimated storage space required for this amount of stock will vary from 9000 to 12,000 sq ft.

Shipping

The orders for customers are picked up by small carts or box trucks moving from bin to bin to collect the items required. When large orders are being filled, the cartons may be left on the pallet or truck and the entire unit brought to the shipping room. Open cartons must be sealed with glue or tape, and the customer's name and address stenciled on each package. Large containers which are shipped loose are tagged with the name and address of the customer. The entire order is then assembled on trucks and is moved to the loading platform.

For export shipment cartons must be strapped with two steel tapes. Regulations require larger cans to be boxed in wooden cases and then strapped. All packages are numbered consecutively, and the names and addresses of the manufacturer and the customer are stenciled on the cases.

Products with flashpoints below 100°F are so labeled with special red stickers on all shipments.

In general, the movement of goods from the filling department to the shipping platform should be in as straight a line as possible and the layout of the warehouse and shipping department should be so designed.

When the order is ready for shipment, a bill of lading is filled out in quadruplicate to record the following information:

Name and address of the shipper.
Name and address of consignee or customer.
Name of shipping carrier or agent.
Date of shipment.
Number of units of each size.

Total gross weight for billing by the carrier.
Notification whether the shipment is prepaid or collect.
Signature of the shipping clerk.

The shipping carrier should be advised one day in advance that the shipment will be ready to allow time for the transportation company to plan daily schedules.

When the shipment is picked up, the bill of lading is signed by the agent who retains one copy as the shipping order; the shipping department retains a copy; the office files the original; and the extra copy is sent to the customer with the invoice for the shipment.

Export shipments usually are handled through an export broker. In making such shipments the carrier receives another set of bills of lading called dock receipts which he presents at the dock for signature. At this point, the goods become the property of the broker who is handling the transaction and he is invoiced as having received the material. The entire responsibility for final shipment, invoicing, and payment from the foreign customer is thereby transferred to the broker.

It is advisable to have the loading platform at truck floor level and protected from the weather if possible. This arrangement will simplify loading operations and will avoid any problems or discomfort caused by stormy weather.

VARNISH MANUFACTURE

The varnish department of a paint unit with a daily capacity of 2000 gal should be capable of producing approximately 1000 gallons per day. This will require 3 fires and 6 kettles varying from 200 to 300 gal in capacity. Depending on the formulations and batch sizes called for, 3 to 6 batches varying from 150 to 400 gal per batch can be produced daily with this equipment.

Basically, the processing of varnishes involves the following steps:

1. Heating the oils and/or resins to a critical temperature of melting, solution, chemical reaction, polymerization, or oxidation.
2. Adding chemical agents when employed.
3. Measuring the progress of kettle reactions.
4. Checking or stopping the action when necessary.
5. Cooling the varnish base to a safe temperature for the addition of solvents.
6. The addition of soluble driers when used.
7. Clarification.
8. Pumping into storage tanks.

Kettle Loading

Oils are stored in tanks or in 55-gal drums. Resins are received in steel or fiber drums, barrels, and paper or burlap bags which weigh from 100 to 550 lb per package. Solvents may be stored in tanks or drums, and liquid driers are usually carried in stock in drum quantities.

A clean kettle is rolled to the loading area. This area should have a manifold pipe outlet from the oil storage tanks, also a loading chute from the floor above or an electric hoist rolling on a monorail directly above the kettle. This arrangement will allow efficient loading without moving the kettle. If possible, the kettle should rest on a platform scale so that all materials can be weighed in.

Oils from the storage tanks may be measured into the kettle by the floor scale, by meter in the pipeline, or by measuring their depth in the kettle with a calibrated measuring rod. Oils in drums are drained either from the floor above or by means of the hoist and monorail to raise the drum above the kettle.

Resins are added by shoveling from the open or split containers into a chute in the floor above the kettle, by shoveling directly from the same floor, or by raising the open drum or barrel above the kettle and allowing the contents to drop in. Care should be taken that the resin is well broken up with pieces no larger than 4 to 5 in. in diameter. This will reduce splashing if oil is present in the kettle when the resin is added and will lessen the time required for melting and dissolving during the cooking process.

Faster and cleaner loading will be obtained if the formulations are worked out on the basis of the contents of full containers in each batch. Extra weighing of containers which are partially filled will be eliminated, and the mess of broken packages which lie around to clutter up a plant and collect dust will be avoided.

The size of the batch will depend on the accuracy and safety measures associated with cooking each particular product. The amount in the kettle should not be so small that immersion of the thermometer bulb will be inadequate for accurate temperature recording, nor so large that, when heat is applied, the foam will go over the top of the kettle and catch fire. If kettles of 200- to 350-gal capacity are used, batches containing as low as 50 gal of solids may be processed. Usually the amount in the kettle is 40 to 50 per cent of the kettle capacity by volume. When oils are being bodied, their volume may be as high as 70 per cent of the total capacity. At a temperature of 580°F the oils will expand about 20 per cent, and allowance for this increase in volume must be considered. In a kettle 48 in. deep, the contents based on the foregoing figures will leave a headroom of approximately 8 in. at the top temperature.

Processing

The fire is ignited and set at a low flame. When it is burning correctly, the filled kettle is rolled over the fire pit. If a fume cover is used, it should be placed on the kettle with its door open. The exhaust system, if it is not in operation, should be started as soon as fumes are visible.

The heat is then regulated to increase the temperature of the batch at the rate of approximately 5 degrees F per minute. A hand stirrer or metal paddle should be inserted into the kettle soon after heating begins to scrape any adhering resin from the bottom of the kettle. Later, when the resin has melted, a mechanical stirrer may be inserted to keep the contents in motion. It is always advisable to continue mixing the batch, especially at the beginning of the cook. This aids in dissolving the resin, prevents localized overheating of the material, and prevents any moisture which may be present from collecting on the bottom of the kettle.

The mechanical stirrer is preferable to the hand stirrer because it saves labor and gives more uniform agitation. The device should be fumeproof and explosionproof, especially if it is to be used when the solvents are added. One or two propellers may be used which are propelled by compressed air or an electric motor with speed reduction gears. The air-driven type is easier to handle because of less weight and has a useful range of speeds from 50 to 400 rpm, whereas the fixed speed of an electric stirrer is approximately 450 rpm. However, a 3- to 5-hp compressor required for an air motor makes it more expensive to install and less economical to operate. The recommended sizes for these devices are 25-cfm capacity for the air mixer and 1-hp for the electric agitator.

As the batch becomes heated and the resin is melted, a thermometer is immersed in the contents by suspending it from the side of the kettle or from the cover so that the bulb touches neither the bottom nor the side of the kettle.

Since water is heavier than most varnish bases, any moisture present will tend to settle to the bottom of the kettle and steam may be formed suddenly with rapid foaming as the temperature approaches 212°F. Careful agitation at this point will allow the water to boil off with no ill results.

Above 215°F, the heating rate may be increased to a gain of 10 deg per min. if most of the resin has been melted. This rate may be kept up until a thermometer reading of 15 to 20 deg below the operating temperature is reached. Then the source of heat is reduced or cut off, inasmuch as the hot kettle and contents will cause the temperature of the batch to increase or coast up the last few degrees.

Operating temperatures vary with the materials used and the product, as indicated below:

°F	Operation or Product
450–500	Liming rosin.
	Resin solutions.
	Pure phenolic varnishes.
	Wrinkle varnishes.
500–550	Addition of drier oxides and salts.
550–590	Oil polymerization.
565–580	Tung-oil varnishes except pure phenolic type.
580–590	Soft-oil varnishes.
600–625	Solubilized natural resins called gum melts.

Batches are held at these temperatures until the reaction or solution is complete and the desired viscosity or results have been secured. The following methods are used for kettle control:

1. When polymerizing oil, the viscosity may be determined immediately with Gardner-Holdt bubble tubes. The refractive index of oil also increases with polymerization, and refractometer readings offer a fast, accurate method of control.

2. For resin solutions, liming rosin, the addition of drier salts, and the running of natural resins, the batch should be clear and completely fluid. Also, a few drops run from the hand-stirrer paddle onto a glass panel should be perfectly clear and transparent.

3. Fairly long cooks may be checked for viscosity by extracting a sample and thinning it in the laboratory to the non-volatile content of the completed formula. The thinned sample may then be tested for viscosity using the Gardner-Holdt tubes and standards.

4. Short cooks may be tested by running a few drops from the stirrer paddle onto a tin or glass panel. Any foam that may form on the surface of the batch should be moved aside and the varnish stirred with the paddle before withdrawal of the sample for test. The panel is allowed to cool to touch and then the drop is tested with the finger. If the varnish is short (high in resin content), the drop will form a hard pill as the cook progresses. If the varnish is long (high in oil content), the operator makes his test by touching the drop, then pulling his finger from the panel, forming a thin string. As cooking continues the string can be pulled out more and more before it breaks. Depending on the viscosity desired, the batch can be held to any length string from 1 ft to the distance between outstretched arms. If processing progresses further, a whisker stretch of many strings is formed as the testing finger is pulled from the panel. Additional cooking will cause the drops running off the paddle to string as the last few drops form long tears. Any further processing is dangerous inasmuch as gelation and complete loss of the batch is likely to occur.

When the desired amount of cooking is reached, the kettle is removed from the fire. If the viscosity of the batch changes slowly, the kettle may be allowed to cool normally to the thinning temperature at which solvents are added. However, if the cooking process must be stopped, some method is used to deter the reaction or cool the contents quickly. For example, litharge or lead acetate may be added to prevent further gelation or the batch may be cooled by checking with the addition of cold oil or powdered resin and flushing the outside of the kettle with cold water. In some plants, water is slowly added to the kettle with good results, by an experienced operator, but extreme care must be taken to prevent splattering of the hot contents.

Thinning

When the temperature of the batch has dropped below 500°F, the kettle is removed to the thinning area. Care must be taken that there are no hot metal spots or sparks, especially on the carriage or bottom of the kettle, which might cause ignition of the hot solvent vapors.

Solvents stored in tanks are measured by volume or metered directly into the kettle. A platform scale at this area is useful but not essential. Since most solvents are used in large quantities instead of drum lots, and are not as varied as the oils, there is no particular problem involved in handling them.

The safe maximum temperatures at which the usual solvents may be added to the kettle are as follows:

Kerosene and dipentene	Below 500°F.
Mineral spirits and high flash naphtha	Below 450°F.
VM&P naphtha and xylol	Below 300° F.
Petroleum naphtha and toluol	Below 200° F.

The thermometer should be removed before thinning the batch. It is important that the solvent be added slowly at the beginning of the operation and that the batch be well mixed. This will prevent sudden vaporization of the solvent or sudden foaming if water is present in the solvent. Then the solvent can be added at the rate of 10 gpm while the batch is being stirred. A mechanical agitator is useful for this operation. If the formula calls for a number of solvents, those which are less volatile should be added first and the lighter fluids held back until the last. As the temperature drops and the batch becomes thinner in viscosity the solvent may be added more rapidly or as fast as 30 gpm.

At this point soluble driers may be added if so desired. If the varnish is going to be used in the paint plant, it is advantageous to omit the driers, or at least those containing cobalt and manganese. This will

prevent skinning in the storage tanks and when varnish pastes are exposed on the roller mills during grinding. However, driers must be added to clear varnishes which are going to be packaged and sold to consumers as such.

Finally the batch is pumped into the storage tanks or into special working tanks for clarification. If the kettle will hold the completed batch, all the solvent may be added before pumping. This is not necessary where working tanks are used before clarification. It is good economy to use intermediate tanks, so as not to limit the kettles to their capacity for holding completed batches, as, for example, a 350-gal kettle will hold 300 gal of finished hot varnish. However, if a working tank is used, the same kettle will produce as much as 500 gal per batch, depending on the amount of solvent added, and several batches can be blended together and adjusted for body and solids at one time.

When the batch is larger than the kettle, the extra solvent may be added to the kettle during the pumping operation or to the tanks. The entire batch can then be agitated by one of the following methods:

1. The pump serves as the agitator. In this case the pipe inlet should be near the bottom of the tank. As the varnish is being pumped solvent is added to the kettle and is pumped into the bottom of the liquid already in the tank with a resultant agitation of the contents. A pump using a 3- or 5-hp motor and delivering 40 to 50 gpm will handle most liquids which may be processed. All pipe lines should be at least 2 in. in diameter.
2. A mechanical agitator may be used which should be equipped with a 3- or 5-hp motor and geared to operate at 125 to 250 rpm. This equipment is necessary if a filter press is going to be used for clarification.
3. Compressed air may be piped into the tank. If this method is employed, the pressure should be throttled and reduced so that the air line will deliver 10 cfm at 20-lb pressure. Here, solvent may be added to the tank, though it is preferable to run it through the pump.

Clarification

For the best results all varnish should be clarified mechanically. This operation will eliminate the necessity of special tanks for settling by gravity and will avoid long storage of varnishes in process.

The three methods and types of equipment commonly used by the varnish industry for the removal of dirt and foreign matter in finished products will be described.

Strainer. The filtering medium for strainers may be made of cheese-

cloth or wire mesh, and the unit may be stationary or vibrating, and either installed within the piping system or detached. In the stationary type, the mesh of the screen may vary from 20 to 80, depending on the clarity desired and the tendency for the screen to clog. This is a special problem in a closed system, which is less messy to operate but more difficult to clean. In the vibrating strainer, the mesh varies from 80 to 200, inasmuch as the vibration will reduce clogging and finer screens can be used.

The varnish can be passed through the strainer by gravity, or, in a closed system which is built into the piping system, it may be pumped through the straining unit. When it is pumped, the pressure should be as low as possible to prevent the dirt from being pushed through the screen. Preferably, the strainer should be installed on the intake side of the pump where the pressure is not so great as at the outlet. The pump should operate to give a flow between 15 and 20 gpm.

The strainer should always be as large as practicable. The larger the area, the faster the flow rate will be and the longer the screen will operate before cleaning is necessary.

In general, strainers are less expensive than other methods, but clarification is much less complete.

Centrifuge. Essentially, filtering by centrifugal force is accomplished in a vertical cylinder rotating at an extremely high rate of speed. The varnish is passed through the centrifuge by entering the rotor or cylinder at the bottom and leaving at the top. In the process it spins with the rotor. Since the dirt in the varnish usually is heavier than the liquid, it will be forced against the walls of the cylinder where it adheres until the end of the operation. Centrifugal machines are compact units about 4 ft high and 1 ft in diameter and are easy to clean. For efficient clarification the varnish should be as warm as possible; if necessary, this can be accomplished by installing steam coils in the working tanks. The rate of flow should be regulated to deliver between 5 and 15 gpm.

Filter Press. Many types of presses are available. Fundamentally, they consist of a series of plates or screens which are covered with cloth, paper, or asbestos fiber. Through these plates the varnish is pumped, leaving all insoluble matter behind. Actually the press serves as a very large strainer having a screen of extremely fine mesh. Unfortunately, the plate coverings clog readily, and, therefore, filter aid is usually mixed with the varnish. Filter aid or diatomaceous silica tends to form layer on layer of filtering material as it is pumped into the filter while suspended in the varnish. These layers hold back the dirt and prevent it from being forced into the pores of the screen covering.

For a small plant a press with 40 sq ft of filtering surface should be

adequate. This type of equipment also filters more rapidly and gives better results with warm varnish. Preliminary to filtering, ½ to 1 per cent of filter aid by weight is added to the varnish in the heated mixing tank. Agitation is continued throughout the entire operation. The cleaned press is filled with the varnish, and, when it is full, the air vent is closed and the varnish is pumped through the filter and back into the tank. This recirculation is continued 10 to 30 min until the varnish is perfectly clear. Then the varnish is run into the storage tank. The pump should give a flow of 5 to 10 gpm. At first the pressure should be low or about 2 to 5 psi. As the filter cake builds up, more pressure will be required to force the varnish through the filter, and, when the pressure runs above 30 psi, the rate of flow will be very slow and the press should be cleaned. Under normal conditions a press should filter 800 to 1200 gal of varnish, depending on the amount of dirt to be removed.

The above methods of clarification can be rated as follows:

	Strainer	Centrifuge	Filter Press
Initial cost	Low	High	High
Operating cost	Low to high	Low	High
Quality of product	Fair	Good	Excellent
Ease of operation	Fair	Excellent	Fair
Neatness	Fair	Excellent	Good

The selection of any one of these methods for the clarification of varnish will depend on the ultimate purpose for which the product is made. Clear coatings for furniture, floors, and woodwork must be clear and transparent. Mixing and grinding vehicles for top-grade enamels must be clean and free from sediment. Flat wall paints and other products wherein the pigments are not finely ground can tolerate liquids for which the standards of cleanliness are not so exacting.

CLEANING EQUIPMENT

The methods for cleaning machines which have been used for the manufacture of paint and varnish must take into consideration the nature of these products. The Northwestern Paint and Varnish Production Club has prepared a brief outline of cleaning procedure as follows:

I. Mixing equipment
   a. Lead mixers, b. Portable mixers, c. Pony tubs
      1. A hand scraper is used to scrape down the sides of the mixers, and a batch of like or similar color loaded into the mixer. Production schedules are followed to hold cleaning to a minimum, such as following a yellow base with orange, red, brown, etc.
      2. Mixers are washed with solvent and a stiff fiber brush. Some manufacturers keep the mixers clean down to the bare metal;

others feel that a thin coating of dried paint prevents color contamination.

3. When mixers become excessively dirty, a solution of caustic and hot water is allowed to stand in them for a period of 18 to 24 hr. The caustic solution is pumped out, and the mixer flushed with clean water and allowed to dry.

d. Storage tanks, e. Change-can mixers

1. In large storage tanks or change-can mixers which have been freshly emptied, a pump can be connected to the bottom and a stream of solvent played on the sides of the tank through a high-pressure nozzle. The feasibility of this system should not be overlooked because at the present time there are pumps which will stand abrasion and give a nozzle pressure of approximately 300 lb.

II. Grinding equipment

a. Roller mills

1. Roller mills are easily cleaned if, after a batch is finished, a small amount of bodied oil or varnish, which is part of the batch, but held out for this particular purpose, is put over the rolls and ground through. The rolls are then loosened, and a rag saturated with solvent is held against the rolls while they are turning.

b. Stone mills

1. Stone mills are mostly classified as to color and used for batches of like color. Scraping removes heavy accumulations. Raw oil run through the mill after a batch gives quite a lengthy protection against undue hardening of any residue.

c. Ball and pebble mills

1. Wash out with reducing liquids held out from batches for this purpose or rinse with clean solvent.

III. Filtering and filling equipment

a. Filling machines

1. Filling machines are cleaned by pumping clean solvent through the machine. Neatsfoot oil is used to protect leather packings.

b. Screens of all types

1. Wire mesh screens used for straining paint are washed in solvent; a stiff fiber brush facilitates the cleaning of the holes. When screens eventually get plugged, they are put in a tank of hot caustic solution and allowed to stand for 18 to 24 hr and then flushed with clean water.

IV. Varnish plant equipment

a. Filter presses

1. Filter presses are cleaned by chasing through solvent which is held out of the batch after the batch is filtered. Solvent loss, if any, is adjusted after non-volatile has been checked.

b. Pumps

1. Pumps and pipe lines are cleaned in the same manner as filter presses.

c. Varnish kettles (open)

1. Directly after the kettle is emptied a small amount of solvent and a long-handled fiber brush are used to wash the kettle. Hard accumulations around the sides are scraped off at various times

or given the caustic treatment. (Caution: do not use caustic in aluminum kettles.)

ACKNOWLEDGMENT

The editors are indebted to F. C. Auwater, C. M. Frey, C. M. Jackson, and S. B. Levinson of the New York Paint and Varnish Production Club; R. F. Brewster and A. T. Montanye of the Pratt and Lambert Company; and H. L. Beakes of the Kentucky Color and Chemical Company for much of the subject matter contained in this chapter, and their contributions are gratefully acknowledged.

OFFICIAL DIGEST BIBLIOGRAPHY

Abbe, P. O., "Pebble Mills for Paint Grinding," p. 20 (June, 1924).

Abbe, P. O., "In Defense of the Pebble Mill," p. 1047 (Nov., 1932).

Appel, F., "Optimum Conditions of Operating Ball Mills," p. 315 (April, 1950).

Atwood, K. F., "Mixing and Grinding," p. 252 (Sept., 1937).

Baker, C. P. and J. F. Vozzella, "Effect of Temperature on the Dispersion of Titanium Dioxide in Alkyd Resin-Mineral Spirits by Means of a Pebble Mill," p. 433 (July, 1949).

Baltimore Club, "Factors Affecting Grinding Efficiency of Ball and Pebble Mills," p. 859 (Nov., 1948).

Beakes, H. L., "Some Principles of Color Tinting," p. 371 (June, 1947).

Berger, L. F., "Operation and Care of Roller Mills," p. 36 (Jan., 1949).

Bonney, R. D., "Roller Mill Grinding—Review," p. 345 (June, 1944).

Bresler, G. A., "Straining and Clarification," p. 678 (Dec., 1946).

Brown, H. M., "Ball Mills," p. 668 (Sept., 1948).

Buckley, J., "Paint Grinding in Pebble Mills," p. 7 (May, 1922).

Cole, E. J., "Varnishes," p. 164 (Apr., 1944).

Fischer, E. K., E. J. Rolle, and L. W. Ryan, "Pigment Dispersion with Ball and Pebble Mills," p. 1050 (Dec., 1948).

Grant, W. J., "Roller Mill Equipment," p. 599 (Sept., 1949).

Gardner, H. A., "Preliminary Notes on Improved Method of Grinding Paints," p. 208 (May, 1939).

Garlick, O. H., "Paint Processing—Postwar, Ball and Pebble Mills," p. 251 (May, 1945).

Golden Gate Club, "Cure Plate as a Possible Tool for Alkyd Manufacture," p. 832 (Nov., 1948).

Kingsley, D. W., "Meters for the Paint Industry," p. 550 (July, 1948).

Kracklauer, A. C., "Filtering and Straining Varnishes and Paints," p. 1065 (Dec., 1948).

Haywood, H. G., "Paint Thinning and Tinting," p. 276 (Oct., 1937).

Langton, J. M., "Specky Varnish—One Cause and Remedy," p. 198 (June, 1934).

Lynch, W., "Mixing and Grinding," p. 244 (May, 1938).

Matlack, R. W., "Stone Mill Operation," p. 160 (Apr., 1944).

McMenanin, J. F., "Grinding," p. 255 (Sept., 1937).

Morehouse, G. H., "Principle of Grinding Paint on a Carborundum Stone Mill," p. 199 (Apr., 1949).

New England Club, "Comparative Study of Hand and Machine Filling," p. 108 (Jan., 1948).

New York Club, "Slack Melt Congo—Its Production and Utility," p. 531 (Nov., 1944).

New York Club, "Study of Pigment Dispersion," Part II, p. 891 (Nov., 1948).

Olson, V. R., "Pebble and Ball Mill Grinding—Review," p. 340 (June, 1944).

Phelps, N. T., "Paint Thinning and Tinting," p. 278 (Oct., 1937).

Powers, J. L., "Paint Thinning and Tinting," p. 273 (Oct., 1937).

Powers, J. R., "Paint Processing—Postwar Mixing and Dispersion," p. 248 (May, 1945).

Reddy, H. A., "Texture of Dry Colors in Relation to Mill Base Production," p. 144 (Mar., 1941).

Rosenbach, M. P., "Pebble Mills," p. 2 (Sept., 1920).

Scott, J. S., "Use of Pebble Mills in Paint Manufacture," p. 13 (Apr., 1923).

Skett, A., "Congo Resin, Methods of Processing and Uses," p. 24 (Jan., 1944).

Stevens, G. R., "Filling and Packaging," p. 1067 (Dec., 1948).

Trussell, E. H., "Grinding of Lacquer Pastes in Pebble and Steel Ball Mills," p. 9 (Dec., 1927).

Vasel, G. A., "Paint Processing—Postwar, Hydraulic Control of Roller Mills," p. 250 (May, 1945).

Venuto, L. J., "Grinding Carbon Black," p. 256 (Sept., 1936).

Weber, W. C., "Simple Guides in Varnish Making," p. 241 (May, 1938).

Wescott, G. H., "Materials and Equipment Problems," p. 254 (May, 1945).

Wheeler, G. B., "Mechanical Action in a Steel Ball Mill," p. 992 (Dec., 1948).

Whitcomb, R., "Thinning, Tinting, Screening, and Filling of Paint," p. 252 (May, 1938).

ADDITIONAL FEDERATION OF PAINT AND VARNISH PRODUCTION CLUB PAPERS

Detroit Club, "Phenomena in Paints and Varnishes," *NPVLA Sci. Sec. Cir.*, p. 247 (Nov., 1939).

New York Club, "Pigment Dispersions," *NPVLA Sci. Sec. Cir.*, p. 313 (Nov., 1934).

New York Club, "Color Strength and Texture Development by Roller Mill Grinding," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 97, 1941.

New York Club, "Clarifying and Straining of Surface Coatings," *NPVLA Sci. Sec. Cir.*, p. 438 (Nov., 1933).

Sparrow, E. E., "Mill Grinding," *NPVLA Sci. Sec. Cir.*, p. 551 (Nov., 1927).

Toronto Club, "Lacquer Paste Grinding on the 3-Roller Mill," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 115, 1940.

Toronto Club, "Grinding of Dark Para Toner," *NPVLA Sci. Sec. Cir.*, p. 451 (Oct., 1930).

CHAPTER 7

PERSONNEL

Selection of Employees

There are many ways to attract applicants to a plant, and it is advisable to use more than one or two methods. Possible sources for recruiting new employees or filling vacancies which exist are included in the following list:

Transfers from other jobs within the organization.
Applicants coming to plant seeking work.
Recruiting workers from friends of employees.
Advertising in newspapers.
Applications received by mail.
High schools and colleges.
Trade schools.
Employment agencies.
Labor organizations.
Fraternal organizations.
Churches.

Selection Aids. Many large organizations use what is known as a personnel requisition. When any department is in need of an employee, the department head fills out the form stating the vacancy, date on which the new employee should start, and the job he will do, and sends it to the personnel department. The personnel department will then seek a person to fill this position.

In companies where job analysis and job evaluation surveys have been carried out, specifications for employment may be devised. These can be of real assistance to interviewers when applicants for positions are being considered. The job specification contains a short description of the job and the qualifications required of the man to be selected. Items included in a specification are the job name, department supervisor's name, job duties, working conditions, wages, lines of promotions, education needed, experience, training, physical, mental and personality traits, and any special skills. The job specification allows the interviewer to present a complete picture of the position to the applicant and in turn he is prepared to select the right man for the job.

Application Blank. The application blank is the most familiar and widely used personnel form. The scope of the application blank is limited and should be adapted to those necessary characteristics which are common to the jobs in the company.

The usual information found on application blanks includes name, date, address, telephone number, date of birth, education, former jobs held, marital status, references, and other questions about an applicant's background.

The application blank should be neat in appearance and designed to create a favorable impression on the applicant, since, in many cases, this is his first contact with the company.

The application blank is highly useful in the screening of prospects. It is comparatively easy to weed out those applicants who show little or no promise; many hours of interviewing time are saved. The application blank serves several purposes:

Provides interviewer with a written summary concerning the applicant.

Screens out individuals who are less desirable.

Saves interviewer's time because normal questions are already recorded.

Prior knowledge of hobbies and interests promotes easy conversation immediately.

Serves as a source of possibilities for future jobs.

Interview. The main purpose of interviewing an applicant is to find out if he or she has the qualifications necessary to fill the position the company has available. The interviewer has the opportunity to gain information from the prospective employee and also to make known certain facts about the company and its employment policies. While the interviewer gains a favorable or unfavorable impression of the applicant, the prospect at the same time creates in his mind an impression of the interviewer and the company he represents. Good interviewing pays dividends in the selection of personnel with the following beneficial results:

Reduces the number of high-cost, trouble-making, questionable individuals.

Increases the number of good applicants so that better candidates will be chosen to fill vacancies.

Increases the skill of the interviewer.

Conserves time required in selection because the less desirable applicants are quickly eliminated.

Increases the respect of the potential employee for the company.

Selection and placement in a company is generally accomplished on the basis of two conferences, a preliminary interview and a final interview. The company's responsibility for the employee does not end with the final interview and the hiring of the applicant. A follow-up interview should be given after the employee has been working for a while to see how he is getting along in his job.

Interviewing is an art in itself. First impressions are very important, and interviews should be held under favorable conditions and in a pleasant location. The size and the location of the facilities where interviews are conducted will be influenced by the number of applicants applying for jobs each day, types of jobs available, how closely the employment department must work with the time schedule of other departments, and the number of interviewers who spend full time with candidates.

The physical surroundings are important. Interviews should be held in private so that both parties can speak confidentially and without restraint. Features which should be considered in this connection are suggested as follows:

> A clean, attractive room is desirable, and it should be large enough to process all those who apply for jobs each day.
>
> Comfortable chairs should be installed.
>
> Heat, light, and ventilation should be regulated to avoid stuffy or groggy conditions.
>
> Good reading material should be provided.
>
> Applicants should be allowed to smoke.
>
> The movement of traffic through the main room should be one way.

Because interviewing is not an exact science, it demands a great deal of intelligence, patience, and spontaneity. Training and experience are essential in developing the art successfully, and the amateur in this work should be taught how to receive strangers, ask questions, and acquire the many qualities required when engaging others in objective conversation.

The individuality of the prospect should be respected and his self-confidence preserved. Applicants should not be kept waiting for long periods of time. It is a good idea to schedule appointments if possible. The interviews should be privately held and free of interruptions. The interviewer should be friendly and helpful; his approach should be very natural and unbiased.

It is important that the interviewer recognize his own tendencies toward bias and prejudice, if he is to obtain accurate information. He should never allow physical or cultural characteristics to influence his judgment.

Many interviewers use a rating scale to record their impressions of applicants. About the only qualifications that can be recorded on an interview rating scale are appearance, self-expression, nervousness, and similar traits, which are graduated from very poor to excellent. The interviewer attempts to score each applicant on this basis.

Before a prospect is called in for the interview, he should be presented with an application blank to fill out completely. After filling out the application blank, he is introduced to the person designated to discuss the position with him.

During the first conference, information is obtained concerning background, experience, education, and training. At this time, it is decided whether or not the prospective employee possesses the necessary qualifications for the job. The interviewer will be able to eliminate many of the applicants and concentrate on a few who will be called in for further discussion.

After the screening interviews are completed, those individuals who appear most desirable should be called back for final review. During this process, it must be decided which of the group will be selected for the job and whether or not the person selected will be a desirable addition to the organization.

During the final interview, the applicant may be given an aptitude test. A good basic test, well-administered and with results properly interpreted, is a valuable aid and useful guide for selection purposes. The tests given must be related to the job for which the person is being hired.

With the combined results and opinions formed, a fairly accurate appraisal of the person selected should be possible.

The applicant approved for the job should be taken to the department head for a final interview and explanation of the position in detail. The final authority with respect to hiring employees for his department rests with the department head who can decide the matter at this time.

If the applicant is satisfactory, he should be sent to a doctor for a complete physical examination before going to work. Meanwhile, the interviewer should check the references of the prospective employee, especially those companies for whom he has worked. In checking references, more direct information can be obtained through personal conversation than from questionnaires or written recommendations and is usually preferred.

Training of Employées

Training is one of the most important functions of management. The cost of a good, well-planned training program can be justified because it

leads to lower unit cost of production. As long as industry intends to manufacture new products, promote, transfer, and dismiss personnel, training is necessary. The one and only way to cut training costs is to introduce an efficient system. Training is of great importance to department heads and foremen because well-trained employees relieve them of many worries. Some of the advantages of training are as follows:

Well-trained employees require less supervision.
Employees gain confidence in their work.
Unit costs are reduced.
Efficiency is improved.
Labor turnover is less.
A good training program is easier to control than indefinite methods.
Accidents are reduced.
Wear and tear on machinery is less.
Opportunity is provided for evaluation of employees for permanent work.
Absenteeism is reduced.

Training Program. Designing a systematic method of training requires a great amount of thought and effort. The program must be supported by top management and tailored to fit the organization.

The first step in designing the program is a preliminary survey to determine the type which is best suited for the organization. The purpose for which a training program is established must be clearly understood. Each part of the job of training must be analyzed in order to determine what each person must know and be able to do to handle his part of the training job successfully.

The next step is a decision with respect to the type of training which will be used. Methods of training can be divided into at least six classes:

Instruction by the department head as the employee works.
Training by a special instructor on the job.
Training by a special department or school for this purpose.
Apprenticeship.
Job-rotation plan where a trainee progresses through a pre-arranged series of jobs.
Conference method whereby two or more employees get together with an instructor for group training.

The type of training program which a firm should adopt depends a great deal on its size. Small firms usually cannot afford elaborate train-

ing equipment. The length of time required for the learning period, wages paid during training, value of raw materials, probability of accidents, and the number of trainees are also important factors to consider before a program is selected.

The type of training program adopted will determine to a large extent what kind of facilities will be needed. If training is conducted outside the plant, a classroom, classroom furniture, blackboards, charts, and many accessories are essential.

If the training is to be done on the job, very little additional equipment is required. An employee handbook can serve as the source of information concerning the company, its policies, rules and regulations, benefits for employees, and many other important matters.

Most of the training should be as informal as possible. If blackboards and training aids are used, they should be placed where they are in full view of the trainees. As many teaching aids as possible should be used, because the trainees will remember much longer what they see and hear than a formal lecture. Teaching should be made as practical as possible and should develop general information about the job before instructions of a specific nature are introduced.

It is essential that instructors have complete knowledge of all the duties and responsibilities of the position under discussion. That part of the work which requires judgment and decision should be separated from the routine and repetitive operations. This information can be secured from the job analysis.

It is very necessary that the trainee understand the background of the operation as well as the job itself. If the work requires a knowledge of mathematics or blue prints, the trainee must be instructed in those subjects before he can absorb any details in this connection.

If the training is not done under working conditions, a good, well-lighted and ventilated classroom in a quiet location should be used. Trainees should be allowed rest periods so that fatigue will not distract attention. It is better to have frequent short rest intervals than one or two long periods for relaxation.

The responsibility for training rests with the department heads and foremen. Good instruction requires considerable skill and a broad understanding of human behavior. The person who gives instruction, regardless of whether he is a staff training man or a foreman, must be able to apply the general methods and techniques of teaching others. In most small firms the foreman or the department head will do most of the instructing. In a large company full-time instructors are employed for this purpose. In either case the following rules should be observed to make the training program successful:

Speak clearly and loudly.

Take an interest in the trainees.

Possess complete knowledge of the job.

Know the simplest and easiest way to get the subject matter across.

Emphasize what you, as a beginner, would like to know about a job which is new.

Use visual aids along with the lecture.

Cultivate patience, and give the trainee time to absorb the information.

Promote questions and discussion from trainees.

Encourage trainees as they show signs of progress.

Never allow period of continuous instruction to exceed two hours.

Never criticize a trainee in public; always be pleasant.

Maintain discipline.

Breaking in a New Employee. When a company decides to train a man on the job, five steps should be followed:

Make the man feel at home.

Take him on a tour of the factory. Show him his job in relation to the finished product.

Make an analysis of the job which will be taught to the employee.

Instruct the man on the job.

Check to see if the employee is following instructions.

When an employee joins an organization, he has a feeling of strangeness and anxiety. This is the time when the instructor should have a heart-to-heart talk with the new employee to make him feel comfortable and win his friendship and gratitude.

A new employee should have an opportunity to take a trip through the plant in order to evaluate his job in relation to the products made by the company. This will make the work more interesting. The new employee should be introduced to the people working in his department.

Every opportunity should be given to learn the necessary background about the job. If the work requires special tools, the use of these must be taught first. After the trainee has adequate knowledge of the background material, the instructor should acquaint him with the rules, regulations, and policies of the department in which the job is located.

The worker should be told about the mechanical equipment which he will handle. The value of the equipment and its maintenance should be stressed. The cost of raw materials and their general properties should be explained.

Before the trainee actually starts to learn, he must be in a natural and

receptive frame of mind. The instructor should explain the job, demonstrate it, and let the trainee do the work while he observes whether instructions are being followed.

Each trainee should be supervised very closely until he has had plenty of practice. Accuracy should be stressed first; speed can be developed later. Frequent conferences with a new employee to observe how he is learning will furnish evidence of personal interest which will be appreciated and create a desire to do satisfactory work.

If a trainee is to be trained away from the job, a definite program should be followed. If the course of instruction is a series of lectures, the total length of the training period should be decided upon and the instructor or instructors should be appointed and advised in advance regarding the subjects they will teach. A complete schedule should be prepared for each hour of the course with provisions for rest periods and quizzes.

When trainees have completed the classroom courses and are ready to work in the plant, the training-on-the-job type of instruction should be used until proficiency is established for each individual.

Employee Compensation

Job Evaluation. Job evaluation is a scientific analysis, within the judgment of individuals, which determines the qualifications that are necessary for a worker to do a job successfully. Specifications are listed in an orderly and permanent form and rates are set on an equitable basis. Some of the advantages of such an analysis are recognized as follows:

Supervisors become better acquainted with their own departments.

Selection and placement of employees will benefit, and job titles can be standardized throughout the entire organization.

Lines of authority and responsibility are more definite.

Labor turnover because of discontentment over wage rates will be reduced.

Better relations with union labor will exist because rates do not have to be negotiated for every job.

Wages may be raised on jobs below standard while not necessarily increasing unit labor costs.

Wage incentive systems will operate more smoothly.

Definite plans for promotion can be adopted by the company.

A sound basis is provided for rate comparisons with other industries in the community.

There are four possibilities for designating the responsibility of installing an evaluation system:

An industrial engineering firm may be engaged to do the complete evaluation.

An outside consultant may be called in to work with key personnel inside the company for this purpose.

An outside consultant may be called in and later hired by the company to become the supervisor in charge of the plan.

The company may decide to let certain well-qualified key personnel in their own organization handle the entire matter.

Job evaluation requires a thorough knowledge of the principles and techniques involved. Experience is important since no standard procedure can be employed, owing to the factors of judgment.

If the company is interested in speed, an outside consultant should be brought in, although there are many advantages in having the work done within the company. Company personnel knows more about the jobs in the plant and, more important, is acquainted with the company's policies. No evaluation remains permanent, and changes must be made which make company supervision more desirable. If the company has no trained specialist in job evaluation, it is better to hire a consultant for the purpose of training personnel in the methods and procedure to follow.

The employee's attitude toward the subject of job evaluation is much more important than the engineering principles employed in the plan. The poorest system from an engineer's viewpoint that has the backing of the employees is far better than the best-engineered program without their support.

Selecting the Plan. The selection of a good job-evaluation plan is difficult because all plans have advantages and disadvantages. The plan that is adopted must fit into the policies of the company. It should be simple and easily understood by everyone involved. The plan should be designed to secure consistency in its application between departments within one plant and also between subsidiary plants. Consideration of such job factors or characteristics as education, experience, physical effort, and working conditions is fundamentally important. Although some jobs cannot be evaluated, a standard plan can be used that will cover most of them, and the few exceptions handled separately.

Most of the better-known systems have real merit. Many types of plans are available and it is up to the individual company to select a plan or a composite of several plans which will serve the requirements of the organization as a whole. Some of the systems of job evaluation are discussed below.

RANKING METHOD. Under this method the jobs are listed in progres-

sive order of importance to a company. An evaluation committee generally prepares a schedule within each department, and then comparisons are made with jobs of similar or equal importance in different departments. Finally and by various means, rates of pay are determined for each group of jobs from the lowest to the highest. This simple, easily performed method proves very useful, especially in the early stages, for evaluations derived from the application of other techniques.

CLASSIFICATION METHOD. The classification method of evaluation is based upon determining in advance a number of classes or grades of jobs and assigning a wage rate or rate range for each class. A general statement of the limits, scope of duties, and responsibilities of work applicable to each class is listed, and jobs are then considered, with or without descriptions or specifications, and placed in one of the several predetermined classes.

POINT METHOD. The point method of rating develops the highly desirable use of minimum and maximum valuations for the various components applied in the job evaluation. Under this system, factors common to all jobs are chosen and numerical values called points are then determined for each factor. Variations in the application of point systems are many. Some systems provide an equal point range for each factor; others set up an unequal point range, the factors being "weighed" according to their importance. Some define or explain how extensive certain factors shall be in order to receive a predetermined number of points. In other point methods only upper and lower figures are given for each factor. Points and, consequently, final evaluations may be directly or indirectly related to wages or salaries.

The point system in combination with other systems is probably the most popular method for job evaluation. This plan is very flexible because any number of factors may be considered and weighted differences may be assigned to each one.

The four common characteristics which apply to jobs are skill, effort, responsibility, and job conditions.

All jobs are closely analyzed in relation to these or a variation of these four factors. A certain number of points are assigned to each of the characteristics determined by the committee doing the job evaluation. In many evaluations these characteristics are broken down further and each portion is assigned a certain percentage of the weight of the characteristic.

FACTOR COMPARISON METHOD. A method of comparison has been developed by Hay, Burk, and Benge. It compares jobs by factors, and then the factors are evaluated in terms of dollars per month or week, the necessity of computing dollar values for the evaluation totals thus

being eliminated. The method utilizes five general requirements or factors believed to be common to all jobs. An evaluation committee uses job descriptions and compares each job, factor by factor, with other jobs previously evaluated. Key jobs are selected throughout the organization. The salaries paid on the key jobs should be in line with the rates for these jobs in the community. The salary paid for each job is distributed over the five factors. For instance, a raw-material handler may be paid $50 a week. Breaking the job down by factors, $20 might be given for skill, $7 for mental requirements, $8 for working conditions, $5 for physical requirements, and $10 for responsibility. All jobs are evaluated in this manner.

Installing the Plan. To be successful, a job-evaluation program must be accepted and understood at all levels of the organization, from top management to the individual worker. It is wise to anticipate the objections from the supervisors, the union, and the employees in advance.

The following advantages will interest the company supervisors:

Job descriptions and classifications are valuable guides for hiring, promoting, and transferring employee personnel.

Rates will be set scientifically for each job, so that problems on wage inequalities will not arise.

Increases and decreases will be easier to adjust.

The following points of the job-evaluation plan should be discussed with the union:

Job evaluation a joint union-management undertaking.

A list of job descriptions and labor grades for all jobs to be furnished to the union.

The application of the plan with respect to discharges and layoffs.

The increase of some job rates and decrease of others and adjustment of out-of-line rates under the plan.

Procedure for the handling of grievances.

Effect of job evaluation on collective bargaining.

Employees should receive personal instruction on the job-evaluation program. The following should be explained to them either in a meeting led by discussion or movies:

Purpose of job evaluation.

How it will affect employees.

Who will do the evaluation.

How the plan will be conducted.

Details associated with the entire program.

When being presented to the employees, the information must be standardized and described to all groups in the same form; complex and abstract facts must be simplified; and the program must be completely explained.

Manuals on job evaluation may be printed and distributed to employees, and posters will help to educate them on the advantages of job evaluation.

Job Analysis. Job evaluation is an evaluation of the job and not an evaluation of the abilities of the person doing the work. Regardless of the type of plan that is chosen, a thorough analysis must be made of each job. The analysis is a complete study of each requirement necessary to perform the work.

The first step in job analysis is to gather detailed information. This is best handled by a questionnaire which is designed and tailored to fit the organization. The form should contain only the necessary facts about the job and should be simple in construction. Questions on the form should be arranged in logical order so that the information can be used later for job descriptions and specifications.

The questionnaire should contain such questions as the following about the job requisites:

A. Mental development
   1. Education
   2. Creative ability
B. Pre-job experience
C. Skill
   1. Self-expression
   2. Judgment
   3. Initiative
   4. Dexterity
   5. Muscular coordination
D. Working conditions
   1. Surroundings
   2. Hazards
   3. Health
   4. Accidents
E. Effort
   1. Physical exertion
   2. Mental exertion
F. Responsibility
   1. Work of others
   2. Safety of others
   3. Records
   4. Tools and equipment
   5. Materials
   6. Production
G. Supervision

The job questionnaire may be filled out by the employee and then checked by his supervisor or it can be filled out by a person who interviews each individual. Every worker should see the complete questionnaire, and his foreman also should check it. If the foreman fills out the form, the employee should check it to see that no important details have been omitted.

After the job questionnaires have been filled out and have been checked for accuracy, the analyst will be able to draft a complete description for every job in the plant. This information should include the following items:

Title—a short, suggestive name that defines the work and one which is commonly used in similar industries.

Summary of the job—a short paragraph stating the duties involved.

Work performed—each specific task and the per cent of time spent on it.

Tools, equipment, materials—a list of these items to help evaluate the nature and complexity of the work.

Physical surroundings—a description of the working conditions, hazards, and physical environment.

Employee attributes—the amount of education, experience, and other things necessary to qualify for the job.

Classifying and Evaluating. All jobs should be classified into as few classes as possible because (1) the rate differentials will be larger and this will set the classes apart more distinctly, (2) there will be a greater chance of finding one or two key jobs for each class. The number of classifications in different companies varies from 5 to 20. An average is approximately 10.

Classifying jobs for a single department would be simple, but jobs must be in harmony with all other departments in the organization.

Classifications will be more in harmony if the evaluation committee selects at least one job or several, if possible, in each department which are similar to each other. This will make it easier to classify other jobs in the company by first identifying those known as bench-mark or anchor jobs.

Through this list the weight can be determined for each factor, such as education, skill, and others used in job evaluation. Bench mark jobs should (1) reflect the prevailing rates in the community, (2) include the range from high to low rates, (3) represent a distribution in chracteristics, (4) represent all types of work, and (5) involve jobs on which the duties remain fairly constant.

The committee should evaluate the key jobs by selecting one factor at a time and applying it to each job on the entire list. For example, in the factor of education, one key job may require an eighth-grade education, whereas another would require a high-school graduate. The jobs requiring more education and more experience and other characteristics would receive a greater total of points than those which demand less. By totaling the points of all factors for each job, it is possible to arrive at a range of points. After it has been decided how many different classes or labor grades of jobs are necessary, the number of classes or labor grades is divided into the point range to arrive at the number of points which will determine where a class will start and end. For example, if the total point range adds up to 180 points and the management decides 10 classes or labor grades are necessary, then the 180 points is divided by 10 and each class or labor grade will have 18 points. Labor grade 1 will be from 1 to 18 points, labor grade 2 from 18 to 36 points, and so on.

After the key or bench-mark jobs have been classified and evaluated, the remainder should be handled in the same manner. The evaluation committee should take one factor at a time and rate every job and repeat until all the factors have been accounted for.

After all factors have been used and points have been assigned, the total points of each job should be compared with those of the bench-mark jobs and all other jobs to observe any discrepancies in the ratings. If any are found to be relatively out of line, the evaluation committee should then recheck these jobs and change the point values of the factors if necessary.

The jobs should now be put into their proper classes. For instance, all labelers should be put into one class or in family groups. Raw-material handlers and others should be similarly catalogued. If any job is out of line in a class or family group, the weights of the factors for that particular job must be checked and revised.

Next, the jobs should be separated by departments, and the approval of the department heads and union heads should be obtained for the way each job has been evaluated. After this has been done, the jobs are ready to be reviewed in relationship to wages.

Setting Up a Wage Scale. After all jobs have been evaluated and points assigned, a scatter diagram should be made to see how the jobs in the plant correlate with the present rates being paid. The total point values found by adding the weights of factors assigned for each job are placed on the abscissa of a graph, and the rates in cents per hour are placed on the ordinate. The title of each job may be written in.

If only one rate is paid on each job, then it is a simple matter to plot the rate on the scatter diagram. If each job has a rate range, then an average of the range should be used. A weighted average based on the number of employees doing the work is more accurate than the mid-point of the range.

After all jobs have been plotted, a line of evaluation should be drawn through the points. This line may be drawn by many different methods. One method of drawing the line is to pick out two or three bench-mark jobs in the higher, middle, and lower classes. A line is passed through these jobs, and all other jobs are judged in relation to the line.

After the scatter diagram has been made and the line of evaluation has been drawn, the labor grades or classes for all jobs should be shown on the abscissa or bottom of the chart.

After the jobs have been plotted on a scatter diagram, it is a good idea to make a local survey to see if the present rates being paid for the jobs are in line with the rates being paid for jobs throughout the community.

The wage survey is best conducted by comparing job descriptions. In this manner those which have similar duties should receive similar rates of pay. Usually a company prefers to keep its rates in line with the rates existing in the community. After comparing job descriptions and rates with many different companies, an average community rate for each job can be computed.

After the community average wage rate for each job has been computed, these may also be plotted on a scatter diagram using the method previously mentioned. A line of evaluation or correlation may be passed through these points as before. A comparison of the scatter diagram of present company rates and the scatter diagram of community rates will quickly determine whether the company rates are in line with community rates.

Starting rates can also be checked in the community at this time to establish the existing rates for beginners or new employees and the predetermined time period for advances.

If the wage survey shows the company's wage rates are lower than the existing rates in the community, the rates should be raised until they are in line.

After the scatter diagram has been completed and the line of evaluation has been drawn, the jobs which fall far above or below the line should be studied; these jobs may have beginners' rates in them or may have been rated entirely too high.

The ideal situation would be to have all jobs fall on the line of evaluation. Those that are above the line should not be reduced immediately

but if possible, men in the high-paying jobs above the line of evaluation should be promoted to jobs carrying a higher rate. This adjustment may take years, but it should be done. Any new employee who starts on these higher out-of-line jobs should be paid a lower rate which is consistent with the line of evaluation. Likewise, the rates which fall below the line of evaluation should be increased to bring them up to the proper level.

In setting job rates, two methods may be used. A single rate may be set for each class or labor grade of jobs, or if the company has a merit rating system, a rate change is preferable since the better workers in the same class have a chance to earn a slightly higher rate. If a class of jobs is assigned a single rate, all workers in that job class will be paid the same rate which is very easy to control.

Maintaining Job Evaluation. Regardless of how good the job evaluation is, it must be constantly reviewed, revised, and brought up to date. Every time a change or an improvement is made on any job, it must be reevaluated. All new jobs must be evaluated and allocated to job classes. Each department should be checked at least every 6 months to determine what changes, if any, have been made which affect the job descriptions and other phases of the system.

Wage Incentives. Wage incentives are a tool of management. They are methods of paying workers in direct relationship to their efforts rather than buying their time at so much per hour. Wage incentives may help to decrease costs since more production is often obtained per working hour.

The ideal wage system is one which obtains the maximum output at the lowest possible cost. This condition rarely exists in any industry, and, as a result, management has adopted many different types of wage incentive plans to approach the ideal production goal.

Surveys made by the War Labor Board show that a good wage incentive plan, properly installed, will increase production approximately 40 per cent, decrease unit labor costs approximately 12 per cent, and increase employees, take-home pay about 17 per cent.

In theory, incentives may be used in any type of plant or industry and almost any product or service can be placed on an incentive basis of some sort.

In actual practice, a wage incentive plan would not be installed in a very small plant with only a few employees since the expense of operating the plan might be greater than the benefits. Also, in plants where installing and administering adequate standards would result in high overhead costs, it would not be practical to use an incentive plan.

The installation of any incentive plan requires plenty of advanced

preparation on the part of management but the time and effort will be rewarded by many advantages, such as: increased production; reduced unit labor costs; increased take-home pay of employees; improved labor relations; reduced labor turnover; reduced absenteeism; and increased cooperation from union and employees.

When management has decided to install a wage incentive plan in its organization, the following points should be given careful consideration so that mistakes may be minimized and the pitfalls which have caused many systems to fail may be avoided:

The wage incentive must be tailored to fit the needs of the individual plant and the operation of that plant. Variations must be allowed lest inequalities result.

The plan should reward the employee in direct proportion to the increased output.

The plan must be simple so that any employee will be able to calculate his earnings immediately.

The base rates on any job must be guaranteed. The worker must be sure of drawing at least his base pay each week.

Provisions should be made for adjusting grievances involving rates or standards.

There should be enough spread between the guaranteed base rate and the incentive rate to provide incentive for the employee to increase his production.

The plan must be installed by competent personnel.

The plan must be sold to top management, union, and employees.

The standards should be guaranteed, if possible, so that the worker will have some feeling of security. The standards should be set fairly for both the employee and the company.

All instruction on the policies and methods of handling the wage incentive plan should be in writing.

No standard should be changed without proper justification. The plan, however, should be written up in such a manner that changes can be made when necessary.

The plan should be constantly reviewed and kept up to date.

A job evaluation survey and a study of methods are essential before a wage incentive plan is installed.

All standards must be based on quality control and material waste.

All incentives should be on an individual basis, if possible.

Department supervisors should share in the plan.

Careful records should be kept for all phases of the incentive plan.

The plan must be constantly maintained.

A good plan should add about 25 per cent to the worker's pay envelope.

Types of Wage Incentives. Wage incentive plans fall into three broad classifications: plant-wide, group, and individual.

If the work is of such nature that several workers or all the workers in a department must cooperate to bring about a good production record, then the incentive should be paid to each individual of the group based on group performance. A group incentive will help to achieve teamwork, and more workers can be included in a group bonus plan. However, rivalry and jealousy may develop between groups and cause labor troubles.

If a workman's output is not influenced by the performance of others, then his incentive pay should be paid according to his output. Most plans today are based on individual incentives.

THE TAYLOR DIFFERENTIAL PIECE-WORK PLAN. This is the most common plan and the simplest form of wage incentive; it works very well for direct-labor operations. In this type of incentive, a time standard is usually set for so many pieces of production per hour or minute. The time standards are usually converted into money and the employee is paid for the production turned out. This plan also sets up standard unit costs when production passes the guaranteed hourly base rate.

It is easy to cut rates under this plan and so unions are not favorably impressed with it. Also a tremendous amount of clerical work is required to change rates when changes must be made. This plan does not lend itself to group incentives.

STANDARD HOUR PLAN. Under this plan standards are based on units of time rather than money. The employee receives 100 per cent of the bonus he earns. It is easy for the men to compute their earnings, and the time saved in doing an operation is used as the basis for the incentive. If a time standard of three minutes has been established and an employee does the job in two minutes, he has saved a minute, or one-third of the standard. He would receive a 33⅓ per cent bonus. The best way to compute the bonus is to total the standard hours for the day and divide them into the actual hours spent during the day. This will give the per cent of bonus earned during the day.

HALSEY OR 50-50 PREMIUM BONUS PLAN. This was the first plan used which guaranteed base rates and expressed standards in terms of time rather than money. In this plan the standard time is set from past production records. Any saving of time by the employee is split equally between the employee and the company. Today very few standards are set by records of past experience. This plan fosters inefficiency on the

part of the workers and allows unit labor costs to vary. It also penalizes workers in the past who have worked efficiently since they have to work harder to reach the standard than the inefficient worker.

THE BEDAUX PLAN. This system is based on a careful job analysis of every operation in the plant. The time it takes to do any job in the factory is determined by time and motion study. Most standards are expressed in terms of the letter B. A point, known as B, is allotted to each minute of the time allowed to do a job. One hour would be 60 points, and an 8-hour day would be 480 points. Each work ticket states the standard points allowed for the job. At the end of the day the employee can add up the standard hours on his work ticket and subtract the actual hours spent from the standard hours to determine the number of points gained. By multiplying the points gained by the value of each point, the bonus pay for the day is calculated.

This plan is easy to install, workers can compute their earnings readily, and it gives management a guide for plant efficiency.

MEASURED DAY WORK PLAN. This plan became popular in the 1930's. Standards are set by time and motion study, but they are applied in a different manner from that in the previous plans. Merit rating is introduced. It is not successful unless an accurate job evaluation of all the operations in the firm has been made to determine base rates. Time and motion study is then employed to set the standards, and the efficiency of the worker is determined. If the standard is $1.00 an hour and the worker operates at 75 per cent efficiency he would be paid 75¢ an hour. If such an efficiency rating has been determined, he is paid on this basis for 3 months at $0.75 an hour. At the end of 3 months, the worker's efficiency is again determined. If his rating is 80 per cent instead of 75 per cent, he will then get $0.80 an hour for the next 3 months. If the efficiency falls, the rate of pay is also cut. This is one of the disadvantages of the measured day work plan. However, the plan does stabilize wages for a period of 3 months, and it is easy for the payroll department to compute incentive earnings.

Supervisor Incentives. It is necessary to consider foremen and department heads in a wage incentive plan. A system based on overhead savings, waste and rejections, reduction in labor costs, reduction in maintenance costs, and reduction of accidents may be adopted.

One way to devise a bonus for supervisors is to draw up an analysis of all the operating factors for which the foremen and department heads are responsible. From this information standards for improvement can be devised. Each foreman and department head should be interviewed, and the standards should be discussed with them. Proper allowances should be made for material shortages and other stoppages of produc-

tion. The supervisors should receive their incentive pay, if any has been earned, each time they receive their base pay. The incentive pay should average 15 per cent to 30 per cent of base pay.

Supervisors may receive annual bonuses based on profit made by the company. An annual bonus does not serve too well as an incentive, because the intervals between payments are long and too many persons influence the operation of a company.

Indirect Labor Incentive Plan. An incentive wage plan should be installed for indirect laborers such as maintenance men, janitors, truckers, and others. A flat percentage bonus should *never* be paid to the indirect workers because it will destroy the incentive wage plan in operation for direct workers.

The standard which can be used for indirect labor is the Standard Hour plan. The standards should be set by time and motion study. Along with the Standard Hour plan, time study may also be used as a basis for an indirect labor wage incentive ratio. The basis of this is the ratio of indirect labor standard hours to direct labor standard hours. By such a ratio any time saved by indirect laborers will be paid to them as an incentive wage.

Installing the Plan. The ideal persons to install the wage incentive plan are qualified engineers in the company. They are familiar with company policies and production methods. Since a good incentive system is constantly changing, company engineers can maintain the plan on a current basis.

If the company's engineering staff is not fully equipped to handle the installation of the wage incentive plan, a good outside management engineering firm should be engaged for this purpose. If possible the company should furnish qualified men to work along with the consultant engineers during the installation of the program. In this way company personnel will be able to maintain the program and keep it up to date.

Many firms have installed wage incentive plans and later dismissed them because of the poor labor relations which resulted. Many mistakes have been made by firms in the past in introducing wage incentives without discussing the matter thoroughly with the employees, who should be informed concerning the entire program and how it affects them.

The top management and all supervisors must be in favor of the wage incentive plan. Since it is management's job to sell the plan to the employees, management must know the program step by step and how it will assist them in making their work easier. For example, the plan will help to simplify and organize the work in each department; decrease unit labor costs; increase the overall rate of pay to employees; establish

a grievance procedure to handle any questions which may arise; cut down absenteeism; reduce labor turnover; and increase the degree of cooperation from employees.

Before the employees will accept a wage incentive plan, they will want to know how it is going to affect them. Many things that should be emphasized to the employees and to the union are listed below.

No one will be laid off because of increased efficiency. Surplus employees will be transferred to other departments.

Workers' overall take-home pay will be higher than straight hourly base pay.

A set base pay rate will be guaranteed each worker.

Employees will have a voice in the standards set in each department. Two or more union employees will work with engineers to help install the plan.

All standards will be set in a fair and equitable manner.

Grievance procedures will be established to handle any questions of unfair standards.

No standards will be changed without due notice and a full explanation.

A general meeting should be called for all employees who will be affected by the wage plan. During this meeting all the steps to be taken in the program should be explained, along with the reasons for the steps, and questions regarding the operation of the plan should be answered.

Films, charts, diagrams, slides, and other pieces of equipment should be used so that the plan will be thoroughly understood and have the approval of the employees or it will be a failure.

Setting of Standards. The prime requisite of a sound wage incentive plan is the establishment of standards which measure effort accurately. If the standards are too tight or too loose, grievances will arise. Standards which are too tight will cause employees to slow down production, with the one obvious result of having employees complain immediately so that it can be adjusted.

Some standards may be too loose which will cause more trouble than those that are tight. A worker's earnings will be too great on a loosely set standard. This will cause other workers to complain. In many instances the worker will be prone to loaf, and, if the standard is not corrected, a permanent loose standard may be set for the job.

When standards have been established they should be permanent and not revised until the job has been changed.

Some base rates on jobs may be set near the break-even point for an operation. If a standard is set at this point then any increased production will result in savings for the company and increased earnings for the employee. Another policy to follow is to set the standard at a point where the average normal operator on a job will be able to earn a 25 per cent bonus. The company should not put a limit on bonus earnings but pay in proportion to output.

No standards should be set on any operation until method studies have been made of the operation. Otherwise a standard may be set on an inefficient method; the operator will find a better method of doing the job, and the standard will be too loose.

A system of handling grievances should be established so that they can be handled when they develop.

When standards are fixed by time and motion studies a sufficient number of surveys must be taken so that a fair standard may be set. Allowances for personal business, fatigue, and delay must be made for each operation. The allowances must be kept uniform for all jobs.

Wage Incentives vs Good Management. A good wage incentive plan cannot be depended on to take the place of good supervision and management. Records should be kept up to date. Time-study men must constantly survey standards, methods, and other factors vital to the wage incentive plan, if the plan is to be successful. Proper scheduling of the work and no stoppages are very necessary for a satisfactory incentive system.

Management should not expect a tremendous increase in efficiency after the wage incentive plan has been installed. The increase in efficiency will be gradual and it may take many months before any great increase can be noticed. Management should allow the incentive plan a fair trial before condemning or praising it. Any form of wage incentive, if considered by management solely in the light of an incentive, may prove workable. A true incentive must be held as a legitimate reward for those willing and able to do their best.

Merit Rating. Merit rating is a method whereby intangible qualities of employees may be judged. In terms of personnel administration, merit rating refers to a type of rating program where the personalities of employees are evaluated objectively. In salary administration the term merit rating is commonly referred to as a type of evaluation where performances and abilities of employees are evaluated objectively.

A company should be very much interested in the personality of its employees. Statistics on upgrading show that employees who rate high in personality usually accept increased responsibility more readily than employees with poor personality. A personality inventory of employees

can best be made by a merit rating plan. Other common purposes of such a plan are as follows:

Helps to pick out employees who are eligible for promotion either to a higher rated job or supervisory work.

Assists management in eliminating unwarranted inequalities or differences in pay.

Identifies men who have the necessary skills and adaptability to fill vacancies on other jobs or to transfer to other departments.

Analyzes the strong and weak points of an employee so that the management and the employee can properly direct their efforts to the development of personal characteristics, skills, or information that will make for improvement and increase his chances of continued upgrading.

Provides a factual basis for wage adjustments or for decisions as to transfers, layoffs, or dismissals.

Enables the supervisory force to do a better job in appraising individuals by giving foremen some concrete factors against which to evaluate personal performance.

Develops confidence in fairness and sincerity of management.

Although many plants have been using merit rating plans for years, such plans generally rate personnel below the supervisory level.

For a merit rating plan to be successful, it must be initiated by the top management. A conference of the executive group should be held, and the advantages of the plan discussed.

A merit rating program will be more successful if those who are going to do the rating are allowed to assist in developing the system. The foremen, supervisors, and members of the personnel department should be brought together in a conference to discuss the overall plans and to decide on the type of rating or ratings which should be used.

Paired Comparison Rating. By this kind of rating each man is compared to each of the other men in the department, such as John Jones vs William Smith. The foreman must choose which man is the better of the two employees. The foreman will base his decision on which of the two men does the better work, on the absenteeism, loyalty, experience, job knowledge, and many other factors. The employee who is rated the most times over the other men in the department is the number-one man.

Rank Order Rating. In this type of rating the names of all employees are listed on a sheet of paper. The foreman then chooses the employee he rates number one in the department. Then he selects the number-two employee, and so on, until all the employees have been

given a number. He will consider the work record, absenteeism, loyalty, experience, job knowledge, and many other factors when ranking each employee.

Graphic Rating Scale. This is the most useful and most common form of rating. The main reason for its popularity is that it allows foremen to rate the factors of personality and to determine where employees are falling down. It enables a foreman to help an employee overcome his difficulties.

In designing a graphic rating scale, certain qualities which employees should have are selected. Department supervisors should be brought together in a conference to discuss those qualities which they consider important in their departments. By having the foremen select the qualities, a better job of rating their employees will be encouraged. Some of the qualities or characteristics which could be included are listed below:

Ambition	Cooperation
Health	Initiative
Loyalty	Intelligence
Care and exactness	Judgment
Rate of work	Safety
Reliability	Volume of work
Ability to follow orders	Quality of work
Future development	Attitude
Overall rating	Personality
Knowledge of work	Ability to get along with people

After the characteristics have been decided upon, the next step is to assign weights to each characteristic. The characteristics which the foremen think are more important should carry more weight than the others. For example: if 10 qualities are picked, qualities such as job knowledge may be given 20 points and loyalty 5 points.

Each quality or characteristic should then be broken down into degrees. For example, it may be decided that each quality will be divided into 5 degrees. The quality, job knowledge, would range from poor, fair, average, above average to superior. The total weight for job knowledge would be distributed among the 5 degrees. If an employee was rated *poor* in job knowledge and the total points for job knowledge are 20, poor would be worth 4 points, fair would be 8 points, average would be 12 points, above average would be 16 points, and superior would be the entire 20 points. This should be done for each characteristic.

After all the qualities have been decided on and points have been assigned to each characteristic and the degree of each, then a graphic

rating scale should be constructed. This scale can then be used to rate the employees.

The next step is the writing of a complete description of each characteristic and each degree. A copy of these descriptions should be given to everyone who will do any rating of employees. By reading and studying the descriptions, every rater will be prepared similarly to make ratings that will be somewhat uniform.

When employees are rated, a definite procedure should be followed. In order to get away from a "halo" effect (i.e., a foreman may rate an employee high in one or two characteristics and have a tendency to rate the employee high in all traits), all the employees in a department should be rated on one characteristic at a time. For example, the foreman could rate all the employees on job experience; then these ratings can be collected before he rates the employees on attitude. This process would continue until all the employees have been rated for all the factors. When all the information has been assembled the total points should be added for the final rating of each employee.

Merit Rating Fundamentals

1. Employees in one department should be compared only with other employees in that department.

2. All employees should be rated at least every 6 months. It is a good idea to stagger the departments with only a few departments rating each month. In this way the personnel department can handle the ratings with less office staff.

3. If possible, each employee should be rated by more than one person. The assistant foreman and group leader should also rate the employees. In this way any personality clashes can be eliminated.

4. After the merit rating system has been in operation for quite a while, a minimum score should be set for each department. When a regular employee falls below the minimum score, he should be put on probation and rated every 3 months until his rating improves. If the employee cannot improve his rating during the probationary period, then this should be used as a basis for discharge.

5. New employees should be rated every 3 months until they reach the minimum score established for their department. After that they should be rated like all regular employees.

6. After an employee has been rated by his foreman, assistant foreman, group leader, and any other interested person, he should be called to the personnel department for a conference with his foreman, assistant foreman, group leader, and personnel manager. His rating

should be discussed with him and any weaknesses should be pointed out. This gives the employee a chance to improve himself.

7. All foremen, assistant foremen, supervisors, and other personnel who will rate employees should be instructed in the merit rating procedure.

8. Any department that achieves superior or above-average ratings consistently should be marked by superior production efficiency, less labor trouble, low accident frequency, and a minimum of absenteeism.

9. All ratings should be confidential. No employee should see the rating of another employee.

10. Foremen should not have access to previous ratings when re-rating employees.

For convenience, the range of scores for employees can be plotted on a graph. In a good merit rating plan, 50 per cent of the scores should be in the middle of the point range, 25 per cent in the below-average group, and 25 per cent in the above-average to superior group.

A merit rating system grows more valuable the longer it is in operation. If the system is honestly handled, employees will be enthusiastic about the method. Management will find it valuable in making promotions, transfers, checking the efficiency of supervisors, locating labor troubles, and handling other management problems.

Human Relations

Successful management is based on efficient production. To produce efficiently, executives must plan, organize, and control the use of funds, materials, equipment, and employees. In the past, management was inclined to emphasize those matters concerned with finance, materials, and equipment, although the human factor in production is equally important. Technological changes have been recognized, but in the field of human relations very little has been done by many companies. Only in the last few years has personnel research been carried on, and many firms are still handling employee relations as they did 50 or 75 years ago, while other aspects of their business operations have steadily advanced.

The complexity of business today has been responsible for the dividing line which exists between management and the rank and file of employees. Executives no longer know the factory workers by their first names. Big business separates the factory manager from the workers. His time is spent in an office, and he is seldom seen in the factory. The personal feeling which used to exist in a small shop between the boss and his employees has been lost. This loss has made the worker

feel that he has no personal interest in the company and partially accounts for his impersonal attitude toward the management.

Mass production has also contributed to the impersonal attitude on the part of employees. The huge volume of production required to fill the demand in all fields has resulted in the breaking up of skilled jobs into many small operations. This has caused a loss of pride in workmanship and job interest. A worker today does not complete a job from beginning to end and his work in many cases may be very monotonous. Routine duties which are machine-like day in and day out must be given special consideration to stimulate interest and relieve the monotony.

Management and Employees. Industry has fallen down in human relations to some extent in not making its policies clear to employees. The first thing that must be explained to the employees is the necessity for the company to make a fair profit. They should understand that the net profit is only 5 per cent or 6 per cent of all earned income and that no firm will exist long without making a profit. It should be emphasized that, although the profits made are not tremendous, they are important in buying materials, equipment, paying dividends to stockholders and doing other things necessary to conduct business. Profits permit the company to stay in business and provide the employees a place to work. Unfortunately, many employees believe that net profits run 20 per cent and 25 per cent of all income taken in by the company.

There are many methods available by which management can distribute information to and communicate with the employees in the factory, such as newspaper advertisements; announcements; bulletins; public address systems; radio; house organs; bulletins mailed to homes; handbooks; and trade association announcements.

Labor unions, political organizations, and many other organizations are also informing employees, and these organizations exert a great deal of pressure and influence on company personnel.

Employees are very much interested in facts and not propaganda, and, therefore, all information should be carefully prepared. Every employee on the payroll is an important public relations man and can be of inestimable value if he likes the company and his job.

All information must be presented in clear and understandable language. The message, to be effective, must be timely, informal, friendly, personal, simple and must explain only one point at a time. It is the duty of management to instruct its employees with respect to policies and reasons for them in order that incorrect information will not be circulated from outside sources.

Employees have individual personalities and desire to be treated as

individuals and not herded into groups. Any pamphlets or literature designed to inform the working staff about company affairs should be put on an individual basis as much as possible. Instead of being addressed "to the employees," messages should carry a more individualistic approach.

Employees are looking for other things in their work besides economic security. People like to control machines, processes, and other individuals. More than anything else they want to control their own destinies, and many companies have failed to appreciate this strong desire.

Employees also want to feel that what they are doing is important. This can be met in part by giving them recognition, and by an evaluation of the job itself. Each individual must be made to feel that his work is necessary and vital to the success of the entire industry.

Intangible factors, such as emotional strain, social contacts, and environment, serve to complicate our relationships with others. Employees must be able to assimilate their likes, dislikes, personal desires, and their social inclinations into their work pattern. Through participation with others, a sense of "belonging" is cultivated which appears to be fundamental to each one of us. Yet many companies fail to realize this basic human need, even though it is within their power to provide a real sense of status. Instead of urging employees to compete with each other, industry should encourage team work and try to make it possible for a man to compete with himself for greater self-development.

Honesty is involved in human relations. Most employees and employers are honest, but industry should constantly cultivate and not discourage this virtue. Individuals will give freely of labor and loyalty to men whom they personally like and believe in. They are also capable of treachery and destructiveness against men whom they distrust and those who exploit them. Good management will build good will and a sense of trust and loyalty among its employees.

Working Conditions. It is difficult for a worker to enjoy doing his job when he has to sit in a draft in the winter time or in a place that is improperly heated. Improper ventilation in hot weather has a similar effect.

When employees complain of difficulties and discomforts in their places of work, they should receive serious consideration, for these things do have a cumulative effect on the general morale.

Other things which lead to better relations are good sanitary facilities, an attractive lunch room, rest and locker rooms, shower baths where dirty work is being performed, and other conveniences.

Human Factor in Production. Production in all industries is still very much dependent on manpower, but the efficiency of every working

staff is only a fraction of what it could be. Higher production efficiency, greater output per man-hour, and lower costs of production are essential to the high standard of living which an ideal society enjoys.

Increased production may be obtained by attacking the problem by three different methods. (1) Each job may be made more efficient through methods study. (2) Relations between the workers can be improved so that they function as a team. (3) Operations can be surveyed and the pace for each job adjusted to meet conditions. The efforts of management should be directed toward all of these methods simultaneously.

To increase individual efficiency in production it must be possible for the worker to be efficient. Obviously, an employee must be given the correct tools, the proper materials, and the right conditions for his work.

An important factor in human efficiency is fatigue. The more repetitive an operation is, the more tiresome it becomes. Because fatigue is a physiological and a psychological condition, the rhythm of doing the same thing over and over has a tremendous influence. Each task should be studied for fatigue, and rest periods established at appropriate intervals.

The amount and kind of light, and the color of the walls and machinery have a direct bearing on fatigue and efficiency. Adequate illumination and a well-designed color scheme for factory painting are recommended.

Relations among Employees and Supervisors. In most organizations production men are interested in machines, layouts, and other production problems and spend a very small amount of time thinking about personnel problems. On the other hand, members of the personnel department spend most of their time with the problems of groups and individuals and very little time on production. There must be a realization by both departments that their functions overlap and that they should be interested in the problems of each other.

Employees work and live in groups and care must be exercised with regard to any change which sets a man apart or against his fellow workers and is likely to do positive harm. Management must also impress upon the members of the personnel department that increased productivity of standard quality at lower cost is the final yardstick in measuring their efficiency as well as that of the plant employees.

Close cooperation between management and the personnel department can help build up a good communication system so that mutual understanding can be fostered and will exist between management and employees.

Today executives should take a new approach to the human rela-

tions problem. It is a well-known fact that all human activity can be broken down into small units of motion. Therefore, the approach of informed management is to simplify jobs till they are simple motions of specialized character. If the speed and rhythm can be varied when tasks are performed, a certain amount of relaxation will result to keep the job interesting.

As companies begin to apply the principles of human relations to their organizations, along with other good engineering techniques, they will find not only that the plant efficiency will increase but also that labor problems and labor troubles will decrease in proportion to their efforts.

Stability and Security. The employee of any firm fears one thing above everything else: unemployment. Under the present conditions of high wages and expensive training, firms can no longer afford to hire and fire workers at will. Production can be kept fairly constant by manufacturing stock for peak seasons during dull periods to avoid lay-offs or shutdowns. Industry as a whole recognizes its responsibility to society and to the community to stabilize production and most employees can now be reasonably sure of employment the year around.

The Foreman

Sometimes, foremen have been selected in a very haphazard manner. Perhaps when a vacancy appeared in the foreman level of supervision, the man promoted was a friend of another foreman or supervisor, a good producer, a good machine operator, the oldest man in seniority, a relative of the boss, and for reasons other than having the qualifications of a foreman. The selection of foremen in some plants has been a result of circumstances rather than ability to supervise.

One of the important objectives of industry should be to develop and maintain keen, well-educated leaders in the first layer of the management group. In order to get men of this type as foremen, a good selection and training program must be devised and followed.

Selection. Foremen should be selected for their courage, emotional stability, integrity, intelligence, and leadership ability. They must be able to plan and keep abreast of the new developments in their field.

In order to obtain men of high caliber for these positions, a survey of the present work force may reveal some good prospects.

A list should be made of all workers who have possibilities to develop into foremen. After this list has been completed, a careful investigation of the work record of each candidate with the company or where previously employed will be of considerable value.

While the work records are being checked, attention should be paid

to the number and nature of outside contacts, reprimands, and grievances. A credit rating should be secured for each man and his community standing should be checked with his neighbors. Activities in clubs and organizations, home life, and financial condition should also be investigated.

Promotions to foremanship should be made from within the company whenever possible. If a company feels that none of the personnel on the present working force is capable of such promotion, men outside the firm should be considered for the job rather than someone who is not qualified.

Any person outside the company who is considered for foreman should be screened and checked more carefully than men from within the company. The applicants should be investigated and interviewed in much the same manner as other employees. However, more care must be taken in each step. (See Selection of Employees.)

Important qualifications for the position of foreman are:

1. Health. The person must be in good health because his physical condition affects feelings and attitudes, modifies actions, limits capacities, and broadens possibilities.
2. Experience. This covers more than work experience or schooling. It includes family life; situations in the past and how they have been handled; other offices and responsibilities which have been held successfully.
3. Training. The type of training the candidate has had in the past and the kind he will need for the future are important.
4. Interests. The likes, dislikes, and indifferences must be matched with other successful foremen to see if these qualities are normal.
5. Aptitudes. The candidate must have the capacity to do the job and the ability to get along with people.

Most of the above characteristics can be determined during interviews with the applicant and by checking references or giving qualified aptitude tests.

The credit ratings, community standing, club activities, and general knowledge about the applicant should be obtained in the usual manner.

Training. Selection and training go hand in hand, and, when a person has been designated for foremanship, the company should do all it can to help him succeed.

Foremen should be trained to develop their ability to lead, supervise, and handle people. The foreman represents management to the workers, and he must be able to convey the plans of management to the employees.

At this level of operations, company policies are put into action and transformed into tangible results.

Several methods are used for the training of foremen which will be described briefly:

Lecture. An appropriate subject is assigned to someone who is qualified to deliver a lecture to a group of foremen. A question and answer period follows the presentation.

Lecture and discussion. A competent person is assigned a subject for a short paper. A discussion period follows in which the foremen discuss the different points brought out in the lecture.

Practical case discussion. This is an important method of training foremen. Foremen pick out the important problems confronting them on their jobs and discuss them with other foremen.

Lecture and movies. A subject is assigned to a qualified person. After or during the presentation movies are shown to supplement the lecture. A discussion period is held so that the foremen can discuss the topic of the evening.

Variations in the type of training and the method of conducting classes for instruction will create more interest than following the same pattern each time that classes are held.

Some of the subjects that the training program should cover are supervisory problems, employee relations, utilization of manpower, merit rating, job evaluation, and wage incentives.

Management and Foremen. During the last few years foremen have seen their power and authority dwindle. Setting rates, handling grievances, scheduling production, and other foremen functions have been taken over by staff men.

The foreman still has definite functions as the leader in his department; in these functions he is the appointed representative for the company and he must be made to feel that he is a part of the management team.

Responsibility and Authority. Companies should state, if possible, the exact duties, responsibilities, and authority of foremen. Once the duties have been put into writing, the company should give the foreman not only the responsibility but also the authority he needs to do a good job. The company should insist that the foremen exercise the authority given them to the fullest extent.

When a foreman is acting according to management policies and instructions, or following through a plan endorsed by the staff, and makes a decision to the best of his ability, the management should back up his decision.

There is no middle ground. The foreman is either a part of the

management or not and if he is accepted as a part of management then he must receive the full support of company officials.

Any foreman who has been on his job for some time will have experience from which executives can benefit. Not only do foremen like to know what the company policies are, they also like to be consulted by top management on new policies before they are put into effect. They do not like to be by-passed on policies. In fact, it is a reflection on top management to set up policies without discussing these matters with the foremen. Executives will find that if the foremen are consulted before putting a policy into effect, it will receive more cooperation when the plan is carried out.

One of the main factors in making the foreman feel he is a part of management is to give him inside information and advise him in advance regarding future policies and practices. Management should inform the foremen on new developments within the organization at the earliest possible opportunity.

The union contract must be thoroughly understood by all foremen in every detail, because understanding the contract will help the foremen to handle properly any grievances which come up and to make wise decisions, especially in dealing with the problems of employees.

One of the most difficult things management has to face is getting foremen to see how they will benefit in terms of higher pay or promotion and other programs set up by management.

Many companies are using a merit rating system for foremen and supervisory performance as a guide to a definite program of promotions and increases in earnings. With a merit rating system, a foreman will not feel that his position is limited with respect to a raise or promotion.

Foremen have the same desires and interests as other workers, and, in addition, they want job security, advances in income and position, with the feeling that they are a part of management and are respected and looked up to as men of substance and importance in the operations of the company.

In a very broad sense, all these factors can be considered forms of compensation. Most companies, however, think of compensation in the much narrower sense of monetary awards.

Foremen may be paid on the basis of departmental efficiency, quality of product, housekeeping, safety, absenteeism, and labor turnover. Many firms have a definite relationship between the compensation received by the foremen and the employees working under them. Some have a percentage setup, for example, where all foremen make 25 per cent more than the highest paid worker in their departments. Other em-

ployers use a bonus plan and the foremen are paid on the basis of individual accomplishments. Since the foremen are responsible for getting out production, making up reports, handling people, and many other problems, they are entitled to direct and adequate financial compensation for these responsibilities.

Foremen and Labor Relations. After the new employee has been introduced to his job and settles down into routine operation, the relationship between him and the foreman is most important in determining whether or not the employee will do satisfactory work.

The wise foreman realizes the most essential part of his job is being able to have things run smoothly and according to schedule. He must learn how to talk, how to listen, and how to think clearly.

A good foreman, in dealing with his employees, will remember to make an appraisal of the situation before arriving at a decision. He gets all the facts, remembers attitudes and relationships, and talks the situation over with the employee in terms he can understand.

The duties of foremanship are very closely associated with human relations. A worker who dislikes his foreman can cause a great deal of trouble. Even though a foreman is very busy and rushed with other matters, he must take time to consider the employee's side of problems when they arise. To command respect he must be fair and treat all employees alike in a firm but not in a domineering manner.

The foreman must show leadership ability. He will get better cooperation by being tactful than by giving orders. Creating a desire on the part of each worker to do his work well will help to develop his leadership ability.

The foreman must build up a feeling of pride in the department for the work it turns out. He must also be able to reprimand a worker and still retain his cooperation. Before the reprimand, the facts pertaining to the situation should be carefully investigated and the worker should be afforded the opportunity to tell his side of the story. If a deliberate appraisal of the facts justifies it, then the foreman should reprimand the worker in private and from an impersonal point of view.

The breaking in of new employees on the job and training others for promotion is a key function of those in supervisory positions. The possibilities of the workers must be determined so that each one is doing those things which he does best.

Several suggestions which may be helpful to foremen in the training of employees follow:

Start each new employee at the beginning of the training cycle.
Be patient with all employees.
Contantly check each new employee to see how he is getting along.

Teach the employees the rules of the department, necessary safety practices, and other things which make for efficient production.

No foreman can possibly apply all the rules and ideas set forth in this chapter. However, a good foreman will try to follow many of the principles that have been presented. If management has been successful in selecting and training its foremen, an increase in efficiency and a decrease in labor problems should be more noticeable as time goes on.

Man Power

The handling of materials has been one of the most neglected operations in production. Companies have spent considerable money for engineering, design of products, layout, sales, advertising, and other phases of business, but less attention has been paid to materials handling. The receiving of raw materials, moving them into stock, and then through the plant to points of production and shipment have been handled in the past by manual labor with very little application of the principles of raw-materials handling.

The handling of raw materials is still a haphazard operation in many plants although some plants are beginning to realize the tremendous savings which can be made by using improved methods. Consolidation of all storage, handling, and transporting functions under one department called the Department of Raw-Materials Distribution will simplify the problem.

Frequently, the employees in certain departments spend as much as 80 per cent of their time handling raw materials. In such circumstances management must recognize the basic fact that processing motions add to the value of manufactured goods, whereas materials handling only increases the cost thereof. Some surveys have shown that it costs more to move raw materials from the freight car to the point of production than it does to ship the materials from the supplier to the plant.

Although increased production may involve additional expenditures for warehousing facilities, the capacity of some plants by arrangement and utilization of space already available has been increased as much as 50 to 100 per cent without additional floor space. For instance, the space above men and machines can be utilized to increase production, and the unit cost of manufacturing will go down.

Economy of Layout. The following facts concerned with the handling of materials should be kept in mind when improved methods are being considered.

Materials are converted from raw stage to consumer goods in three operations: assembling, processing, and distribution.

Materials handling: studies reveal that a unit of material may be handled from 20 to 150 times before the final product is shipped. If a ton of material is moved 10 times, the company must pay for moving 20,000 pounds of weight. The average cost of moving material in the United States is about five billion dollars a year.

Defective merchandise: often damaged finished goods are as much a result of improper materials handling as defective workmanship.

Safety record: poor materials handling causes 30 to 40 per cent of all industrial accidents.

The layout of a plant determines all production activities, including the flow of materials. Manufacturing consists of a series of processing operations, and materials must be moved from one process to another. In many plants the development of new methods and procedures for handling materials is left to department heads. Most line executives are usually overburdened with regular duties and can devote little time to layout and improvements and therefore, can hardly be expected to keep abreast of all new developments. Every foreman or supervisor who is affected by a change in layout or materials handling should be consulted in regard to the new plan but the final design and execution of the plan should be left to qualified engineers.

The materials-handling system should be incorporated into the layout of all new plants. A study of existing plant layout and materials handling is indicated when the following conditions prevail:

A male employee lifts material from the floor to a point above his head, or a female employee lifts material from the floor to chest height.

More than one operator is required to lift or move material.

A male employee lifts more than 75 pounds above the knees, or a female employee lifts 35 pounds above the knees.

An employee is engaged in handling raw materials for more than 30 minutes constantly each day.

Employees handle similar materials daily over long periods of time.

One or more employees move a large amount of materials for a greater distance than 50 feet.

Many well-designed layouts are not operated properly, and trouble results. The following circumstances suggest that a problem in the handling of materials exists:

When the receiving department is jammed with materials, truck lines and railroads complain of delays, demurrage is a weekly problem, accidents are numerous and a lot of overtime is necessary.

When storerooms are crowded, materials are damaged, too many stock clerks or materials handlers are needed, materials are lost and inventories are in poor shape.

When materials must be rehandled and stored several times, skilled operators must handle materials, the total manufacturing time is long compared to actual processing time.

When traffic aisles consume more than 15 per cent of floor space, aisles are congested and hazardous and service to production equipment is difficult.

When employees complain of heating, lighting, ventilation, efficiency is poor, accident rate is high and labor turnover is great.

When foremen complain about lack of floor space and overhead space is unused.

Movement of Materials. When the flow of work is intermittent and the sequence of processing motions must be interrupted, suitable methods of moving the material must be devised. One of the methods of transfer is by the fork truck. The material is moved on pallets and skids or set up and handled in truck and trailer fashion. (See Chapter 1.)

The fork truck, pallet jacks, and hand-lift trucks have helped to increase the efficiency of many plants. Materials can be delivered quickly and economically from storage areas to points of operation.

The equipment used in moving and storing materials should have sufficient capacity to handle them continuously and swiftly with a minimum of damage. In many instances, belt conveyors, chutes, and portable conveyors may be employed.

When the flow of work from one operation to another is uninterrupted and at a fairly constant rate, the best means of moving material is by conveyors. If possible, they should be standardized so that they can be moved from one location to another. Jigs and fixtures should be made interchangeable so that they can be used at any point in the plant.

The assembly-line method of production has been used where goods on a conveyor pass by an operator who has one very small operation to perform. Many plants have a group of workers who move down an assembly line; they will do one thing to the material at one time, and, as the next material comes down the line, they will perform a different operation until the employees complete a cycle of operations. Monotony is broken up, and more work is accomplished. By this method, the employees are moved to their work instead of moving the materials to the employees.

Finished goods in a warehouse may be handled in many ways. Belt conveyors, fork-truck-pallet systems, and other methods are used. Good

materials handling in the warehouse will greatly increase the efficiency of shipping.

Whenever materials are pulled by hand, placed on an elevator, or stacked by men, costs go up. Belts and conveyors should be used to carry finished goods to the warehouse, as well as to freight cars and trucks.

Many companies use pallets as a means of storing finished products. The pallets are moved to the freight cars for shipment, having many hours of handling labor. The empty pallets can be stored at the loading dock until a sizeable pile is accumulated, before returning to the warehouse for the storage of more finished goods.

Efficient Materials Handling. The person in charge of materials handling should be familiar with available handling systems, both manual and mechanical. The methods selected should be supplementary rather than competitive. Many types of systems can be used but they must be integrated into a smooth working whole.

Before any new equipment is purchased, it is wise to determine whether the present equipment is being used effectively.

To bring the handling of materials in line with production standards, the following steps are recommended:

Place the responsibility and authority for the handling of materials under the direction of one individual.

Employ good personnel.

Make constant study of methods for improvement.

Provide a good communication system between the production departments and the personnel for moving raw materials to the proper place.

Select and standardize the mechanical equipment suited to the job.

Maintain and replace old equipment when necessary.

The efficiency of all plants can be greatly increased by the application of modern methods for the handling of materials. Alert management will encourage and support an overall program directed to the reduction of unnecessary waste of man power.

Work Simplification

Work simplification is a field, a way of thinking, a philosophy—not a package. Allen Mogensen defines work simplification as a common sense method for the elimination of all waste of time, energy, and material—which means taking the headaches and backaches out of our daily work. It embraces not only the dreaming up of little gadgets to save effort on a specific job but also the background thinking as to whether the job is necessary. It is a target program with the aim of eliminating all nonessential work and improving other methods of work.

During the last ten years, industry has begun to realize the tremendous possibilities of methods improvement. Management has acknowledged that each job and operation may be done more effectively and efficiently than by the present method. The Ford plant at River Rouge increased its production by 45 per cent through the adoption of a methods simplification program.

Work simplification is one of the methods by which unit costs can be lowered and production increased without buying new equipment, adding more floor space, or employing more labor. To maintain a favorable competitive position, the necessity for a program of this nature is apparent.

Standardization and simplification have many possibilities. The number of products and lines may be cut down. Special tools and fixtures may increase production and cut costs. If materials can be resolved into a few classes, the amount of raw materials on hand may be greatly reduced. Supervision and inspection are much easier where methods, equipment, and products have been simplified.

Clerical work and records should also be surveyed. A study of the total number of forms in use, the number of copies required, the filing system, and office methods may help to reduce overhead costs.

Before any beneficial results can be observed from the program, a company must have good industrial relations. If the industrial relations in a company are poor, the plan to increase efficiency has little chance for success. Unless everyone in the entire organization supports the plan, it will not be successful.

Work and methods simplification is a full-time job. A department or one of the staff should be selected for this purpose. If simplification is relegated to time-study men, engineers, or supervisors to do in their spare time, it will never be done well, because of interference with regular duties. For this reason a plant-wide training program for work simplification is recommended.

Improvement Method. The method of making job improvements must be taught to every person in the organization from the president of the company down to the lowest-rated job in the factory. Making job improvements is very simple, and almost everyone with some practice will be able to make suggestions. The steps to be followed are listed below:

1. Someone must be aware that a job should be changed and simplified. The suggestion of change may come from an employee, foreman, or methods engineer. The details are learned at this time.
2. A description of the method now being used is written and recorded on a process chart. Each sequence of the job should be questioned.

3. The record of the present method should be made by the methods engineer who should analyze the motions or sequences. The name and description of the job and time necessary to complete the operation should be expressed in writing.

4. The person who suggested the change, department head, methods engineer, and employee working on the job should talk over a better method of doing the work.

5. After the above group has agreed on a proposed method, it should be given a trial to see if it is practicable. The work should be organized and the necessary changes made in layout.

6. After the "bugs" have been worked out of the new method, a description should be written and a process chart made. The new chart should be compared with the old and the improvements noted.

7. The operator should be taught the new method.

8. The job should be checked from time to time to see if the operator is following instructions and the method is working as it should.

9. If the company has an incentive plan, a time standard should be set for the new method.

The Process Chart. This is one of the main tools used in work simplification. The chart itself does not improve the method, but it does allow the methods engineer to write up the data in such a way that an analysis is readily available.

Of the many types of process charts, the methods engineer should use those which are best suited for his purpose. The best charts will present a bird's-eye view of the job without detail. The four principal types are:

Operation chart. It follows processes wherein many parts come together for final assembly.

Flow process chart. It shows the flow of materials, forms, or operators through a given process.

Man and machine process chart. It shows the relation between the part of the cycle under control of the operator and the part controlled by the machine. This chart will help uncover idle machine time.

Operator process chart. It presents a detailed picture of a single operation. It shows the functions of the right hand and left hand of the operator.

All the above charts are used by methods engineers in simplifying jobs and methods.

Training for Work Simplification. The first to be advised in methods improvement should be the top management group. They should be

brought together for a short series of conferences, and the advantages of a planned program for work simplification should be discussed. Top management should do the following things to ensure a successful work simplification program:

Pick seasoned, competent persons and give them the best training in work simplification available.

Plan all activities of manufacturing, distribution, and selling to make a better product at a lower cost.

Appropriate funds for projects and for setting up a simplification department.

Select and examine major projects.

Determine the length of time to realize results.

Determine the length of time required for supervisors and employees to adjust themselves to change.

Protect those employees whose interests may be jeopardized by technological changes.

Employ and train supervisors who are competent to deal with both the technical aspects and industrial relations pertaining to the program.

Discussions with secondary management should include junior executives, supervisors, and foremen. This group should be impressed with the way methods simplification will make their jobs easier, reduce unit costs, increase production, and save time and decrease waste throughout the plant.

The supervisory group should be given the following responsibilities:

Examine and judge the technical, financial, and personnel aspects of recommended developments.

Check needs for better methods in their respective departments.

Plan the changes to be made in their departments.

Install new procedures and follow through the change-over periods.

Reassign and retrain workers.

The third and most important group in the work simplification program is composed of the hourly paid employees. For the program to be a success, the company must have the support and participation of the employees. Their support must be obtained voluntarily, and, to do this, management may offer some type of incentive. Obviously, employees are making a direct contribution to management and will receive a feeling of satisfaction and worth. Better-quality products at lower costs will place the company in a better competitive position, and the employees will have greater security.

Management should keep in mind that people resist change. They

like to repeat a routine to which they are accustomed, will defend established practice, precedent, tradition, custom, and will resist new ideas.

The application of work simplification can be made so practical and so desirable that employees will want to participate in it. The program should be presented as an opportunity to obtain and use new techniques to demonstrate ability.

Training classes should be held during working hours but attendance need not be compulsory. Employees who do attend should be paid their regular rates and relieved of duties during the meetings. Lectures, movies, and demonstrations can be used to emphasize the benefits of job improvements. Process charts should be explained, and the employees should be allowed to work out simplification problems so that they will understand the entire procedure involved when making changes in their own departments.

Follow-Up of Plan. After the simplication program has been adopted by the company, a tailoring job may be necessary to make the plan fit each department. A standard practice procedure should be written including the duties and responsibilities of top management, junior executives, supervisors, foremen, and employees.

Everyone in the company should be acquainted with the plan and how it operates. Foremen, especially, should encourage employees to suggest changes, and action should be taken immediately after suggestions are received.

A method of reporting the changes that are made should be devised. The results should be passed along to everyone in the company.

Improved methods should be made known to all employees, and appropriate credit given to the persons who have recommended the changes, by verbal recognition, letter of appreciation, bulletin board, employee publication, and other means.

A work simplification program for improving methods and jobs is beneficial to any company regardless of size. It can be used to simplify any operation in the office or factory regardless of type. It is a constructive effort in which management and employees can share to reduce costs through cooperation.

Supervision

Management employs production control to schedule production and to keep it moving at an economical pace. Production control is broader than merely planning, routing, scheduling, dispatching, and follow up. In addition to these, control must be coordinated with quality, inventories, materials handling, and other things which are necessary for uninterrupted production. Men, materials, and equipment must be

brought together for the purpose of manufacturing a desired quantity of products of acceptable quality in the most economical manner.

Production control is essential; it need not be elaborate for the small plant, but it should be flexible. The value of production control increases as the amount of sales, products, operations, and employees increase.

Planning. Good supervision anticipates difficulties before they arise and takes steps to prevent their occurrence. Predictions are required for materials, delivery dates, the application of men and machinery, tools, and production time necessary for a given period, which may be one month, three months, or a year.

Planning involves all elements of the business and progresses from the board of directors to the lowest level of supervision. Before a good job of planning can be done, the management must know what rate of production makes the most efficient use of men, equipment, and space. This will give the lowest unit cost, which is the goal of production control.

Planning production usually starts with a sales forecast. The volume of sales for each product, based on past experience, dealer check-ups, promotional programs, and business conditions, is estimated in advance for a certain period. Production is then geared to the estimate, and the estimate serves as the pattern for overall manufacturing operations, equipment requirements, material purchases, and working schedules.

Some companies prefer to base production on stock requirements rather than sales estimates. To maintain inventory at the established level, maximum and minimum stock limits are set and orders are placed in the factory. This system ties up working capital, requires extra storage space, and increases handling costs.

Other concerns manufacture according to the orders they receive from customers. When an order is received, it is planned, scheduled, manufactured, and shipped. This system requires relatively small capital, very little storage space and cuts down costs incidental to inventory. However, business handled on this basis is subject to tremendous fluctuations in production, which can become the source of labor troubles, increase overtime wages, lose customer good will, and introduce many other problems.

Manufacturing Program. The first step in manufacturing is the design of the product by the laboratory to meet either the specifications of the customer or the requirements of the consumer. If the operational path and sequence which the product will follow has not been determined, then this should be done by the engineering department.

The second step in manufacturing is to see that the proper amounts of raw materials are on hand to keep the production moving at a steady

rate. In most companies a certain minimum stock of raw materials is kept on hand, and new supplies are ordered as the inventory is depleted. No new product should be started until the necessary materials are available. If the materials are not in sight, the order to manufacture the product should not be released.

Scheduling. Scheduling of production is highly important since it designates the flow of work through the plant and the amount of time necessary for each operation. In straight-line production, if the capacity and the time of flow through the line are known, it is relatively easy to schedule production in advance. In plants where batches or jobs must be scheduled, the problem is more difficult. It then becomes necessary to assign three or more batches in order of sequence to each machine. Each batch should be routed through its various operations to completion.

Many times it is necessary to change and revise schedules and provisions must be made to accommodate these changes quickly and without upsetting the whole program.

If schedules can be set up graphically on a chart, they can be followed more easily. A visual chart, if properly set up to include the jobs on each machine, the line of operations through which each batch will pass, and the location of each batch in process at the present time, will show the schedule for the complete factory. A scheduling system of this type can be maintained only by constant rearrangement.

Two of the best-known visual scheduling devices are the Gantt chart and the Taylor board. The Gantt chart has a line set up for each machine or group of machines. The line is divided into time units. The production operations for a job are figured in units of time, and this is marked on the board for the machine.

The Taylor board is more simple than the Gantt chart. Each machine or production unit has three pockets or clips on the board. The first clip shows the job on the machine at the present time. The second clip or pocket shows the next job for the machine, and the third pocket holds the next job or jobs which are scheduled. The Taylor board does not show the time when a certain job should be completed. However, after a clerk has worked with a Taylor board for a short time, he will be able to estimate closely the time that it will take to complete each operation. The big advantage of the Taylor board is that jobs can be shuffled around easily by just moving the cards from one pocket to another.

Many mechanical visual scheduling devices are available such as pegs, strings, holders, tape, and others. These charts are useful not only for production parts, assemblies, and machine loadings but also for purchases, labor schedules, budgets, credits, and inventories.

Control boards can be used very economically in small plants, as well

as large ones, and can be adapted to almost any type of manufacturing. The system employed should be quick, compact, accurate, economical, simple to operate and understand; it should be handled by competent personnel.

After the production schedule has been made up, information must be transmitted to the foremen and employees. When an operator reports his present job is finished, he may receive a work order to start another job or the foreman may be supplied with a schedule of jobs for a certain period and have the responsibility of assigning the work as operators and machines become available. In the latter event, the clerk at the scheduling board should be notified.

After the production control clerk has dispatched a job to the foreman or worker, the order must be followed through the organization to see that it is completed on schedule.

The superintendent usually follows production through the plant, and, if jobs are delayed, he can take the necessary action to get things moving again. If each batch has to be followed up, then the production control system is falling down and some changes should be made, especially in planning and scheduling. When the system is working properly, foremen will be relieved of annoying problems which interfere with supervision of their departments, maintaining production schedules, and training men.

Inventories. After World War II, materials were so difficult to procure and delivery dates were so uncertain that most firms bought all the materials they could obtain. When shortages do not exist, the attitude of management changes and inventory control is recommended. Large inventories are inflexible, tie up capital and floor space, and cause losses due to obsolescence. Perpetual inventory systems are recommended for both raw materials and finished stock. These records make it possible to spot a depleted supply on the one hand and to avoid huge stocks on the other.

As has been stated, materials handling is one of the expensive manufacturing operations. Many times machines and men can be moved to the materials. Fixed machinery has been replaced in many instances with mobile units to reduce costs of unnecessary handling of inventory.

ACKNOWLEDGMENT

The editors are deeply indebted to L. J. Ringler of the Lowe Brothers Company for the subject matter contained in this chapter, and his cooperation in this connection is sincerely appreciated.

OFFICIAL DIGEST BIBLIOGRAPHY

Blanke, H. B., "Questionnaire Supervision," p. 5 (Jan., 1929).
Carlton, F. T., "Unemployment Insurance," p. 133 (Mar., 1935).

Fasig, E. W., "Classification and Descriptions of Jobs in the Paint, Varnish and Lacquer Industry," p. 478 (Nov., 1942).
Fisher, E. M., "Foremanship in Our Industry," p. 32 (Jan., 1946).
Haake, A. P., "Dilemma of Management," p. 959 (Dec., 1950).
Heckel, G. B., "Value of the Paint and Varnish Production Clubs to the Industry," p. 1 (Jan., 1924).
Heckel, G. B., "Why Is a Production Club," p. 3 (June, 1924).
Heckel, G. B., "Industrial Civilization and the Production Man," p. 4 (Sept., 1924).
Heckel, G. B., "The Social Necessity of Cooperation," p. 1 (May, 1925).
Heckel, G. B., "The Age of Cooperation," p. 7 (June, 1926).
Hopkins, H. H., "Teamwork: Sales, Production and Technical," p. 894 (Dec., 1949).
Katinsky, H., "Man and Mill Hours," p. 300 (June, 1940).
Miles, H. E., "Organization," p. 369 (May, 1950).
Munn, R. J., "Cooperation," p. 23 (Jan. 1929).
Rich, J. M., "Labor Turnover, Its Control and Reduction," p. 4 (July, 1925).
Shuey, R. C., "Another Thought on Personnel Problems," p. 111 (Mar., 1946).
Stark, R. C., "Factory Management in the Paint and Varnish Industry," p. 212 (June, 1937).
Stark, R. C., "Production–Supervision and Costs," p. 297 (May, 1944).
Sterne, E. T., "Has the Technical Man a Place in Business Administration?" p. 658 (Nov., 1931).
Trigg, E. T., "Production Personnel," p. 347 (Dec., 1936).

ADDITIONAL FEDERATION OF PAINT AND VARNISH PRODUCTION CLUB PAPERS

Munn, R. J., "Thirty Years Experience in Varnish," *NPVLA Sci. Sec. Cir.*, p. 579 (Nov., 1927).
Robinson, F. W., "Some Operating Wastes in Our Industry," *NPVLA Sci. Sec. Cir.*, p. 284 (Oct., 1926).
Stauderman, A. C., "Factory Organization From the Production Man's Viewpoint," *NPVLA Sci. Sec. Cir.*, p. 608 (Nov., 1927).

CHAPTER 8

FACTORY COST ACCOUNTING

A comprehensive cost system serves as the rudder for a business. It enables the management to direct a course true to the fundamental policy governing the enterprise. Without such controls the course is uncertain and may drift toward dangerous shoals which might cause disaster. The history of successful manufacturing concerns indicates that a true knowledge of costs is one of the pillars upon which success is built.

Many smaller manufacturers think cost systems are expensive to operate and particularly troublesome. This opinion may be founded on some sad experience with a system which was not practical. To be of most service, the system must be extremely simple and free from complicated details. In fact, it should merely tie together production records and the indispensable accounting for payroll, raw material purchases, and expense account payments.

The expenditure incurred in figuring costs has been found by many companies to be less than ¼ of 1 per cent of sales. In other words, it costs only 25 cents to obtain true knowledge of the cost of products for a sale amounting to $100. This nominal expense is more than justified by the security it provides.

The cost of manufacturing a paint, varnish, or lacquer is much more than the direct labor employed in the actual production. The labor necessitates supervision. Machinery is required, and this uses power. Also, the buildings occupied, as well as the equipment, are subject to depreciation, insurance, taxes, maintenance, etc. Thus such overhead expense must be included to determine the complete manufacturing expense.

A study of the manufacturing expense of many manufacturers indicates that it is composed of approximately:

Labor	25–50%
Expense	5–15%
Overhead	50–70%

Manufacturing costs of individual products differ to so great an extent that averages cannot be safely used. A manufacturer figuring

at an average cost will probably find himself receiving orders for those items on which the actual expenditure is high, and failing to secure orders because of high prices quoted for products in which the expense incurred is less than the average. Thus he would receive orders for unprofitable items while competitors would be favored with those affording greater profit.

The complete labor, expense, and overhead to manufacture a product in bulk, ready for filling into containers, varies greatly, depending on the formula, type of equipment used, and the quantity produced in one continuous run. Small runs naturally cause excessive manufacturing expense, and the cost may be several times as much as when manufacture is in full batches.

Careful study should be made of each individual product or group of products, and a standard or normal manufacturing cost should be set for each product or group. This standard should cover the full batch quantity which can be made most efficiently and economically in the equipment available. It should cover the cost of mixing, grinding, thinning, and shading the product up to the point of filling. There is a great difference in the manufacturing cost of individual products as well as a wide variation in the cost of the same product manufactured in different plants, depending on the character of the equipment and the quantity produced at one time.

At the same time, due consideration should be given to the added direct labor and expense incurred when fractional batches are made. Obviously, every effort should be made to produce in quantities as large as conditions will permit.

Every manufacturer should sell his product with exact knowledge of whether his price is above or below cost and what profit will be realized on the sale. Products sold at a loss represent capital and labor thrown away. Such sales inevitably result in a curtailment of industrial activity and greater unemployment.

The study of cost details will reveal inefficiencies in production methods or use of materials and will furnish to individuals, responsible for various divisions of the factory operations, complete reports of the details of the work under their immediate direction. It provides constant reports, showing what is happening in the plant rather than what has happened, and suggests immediate correction of inefficiencies.

As business primarily must make money in order to exist, it is obvious that the product must be disposed of for more than it costs. It is said that 95 per cent of those who enter business fail. Probably no one feature influences a manufacturing enterprise more favorably than a dependable cost accounting system which will provide a correct measure

of profits. Every manufacturer, therefore, is vitally concerned in knowing the actual cost of his product.

The problems presented in the use of materials and in operating costs make it necessary for the manufacturer to determine and know constantly the cost of his product in order that his business may continue to be a profitable one, earning the margin of profit desired.

Thorough cost-accounting methods will determine the cost of making a complete salable product and delivering it to the carrier for transportation and will record the various elements that go to make up such cost in a comprehensive manner. Individual products which may have been marketed on an unprofitable basis, as well as those most profitable, will be revealed.

The system must present such cost data very promptly and concisely. Delayed costs are almost useless.

A proper cost system, both for manufacturing and selling, should tie in with the general books of the company so that the financial statement will reflect all conditions of the business accurately.

The following chart and outline illustrate the successive steps through which the cost and selling price are built up. A study of these and the explanatory remarks which further define individual captions should serve as a guide for small and large manufacturers to determine accurately the cost of paint, varnish, and lacquer products. They represent the one best way to determine the cost of products of the industry.

OUTLINE OF COST FIGURING SYSTEM

The cost of paint, varnish, and lacquer products comprises the following elements:

Material.
Package.
Labor.
Expense.
Overhead.

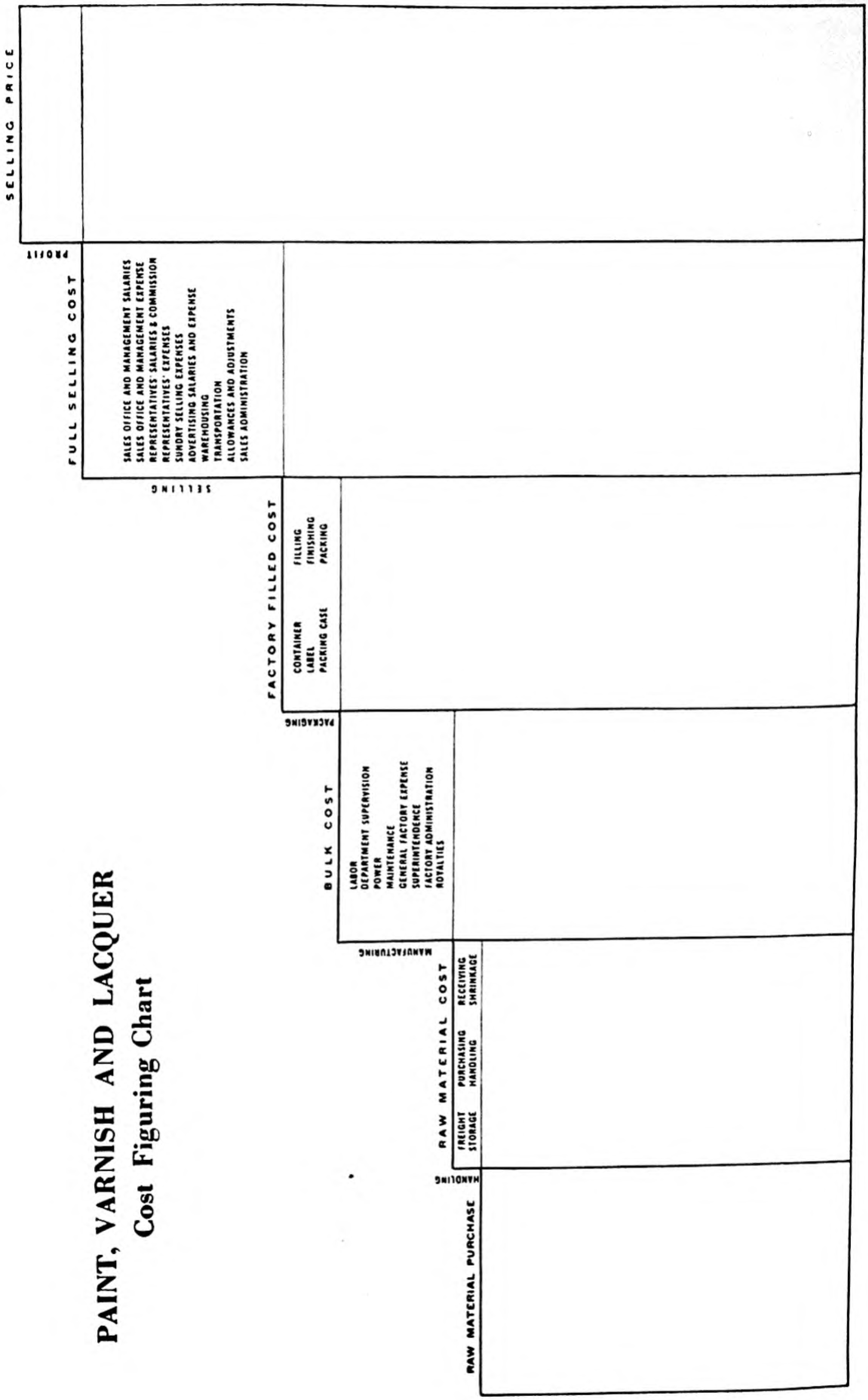
To standardize the terms used to designate intermediate steps in Cost Figuring, the cost may be divided into four major captions:

1. Material cost.
2. Bulk cost.
3. Factory filled cost.
4. Full selling cost. (To estimate selling price.)

Material cost includes all raw materials used in manufacturing the product.

Bulk cost represents the product in bulk ready for filling into packages and shall include—

Raw material.
Labor.
Power.
Factory expense.
Factory overhead.



PAINT, VARNISH AND LACQUER
Cost Figuring Chart

Factory filled cost includes the above cost of the product in bulk, also the container, packing case (if any), and other expenditure needed to prepare the product for shipment to the customer.

Full selling cost embraces all the foregoing items of expenditure and in addition thereto an estimate of the cost for selling the product and the services required by the consumer.

Selling price should cover all preceding elements and include the desired margin of profit.

OUTLINE OF COST FIGURING CHART

Raw Material Cost. Complete cost of raw material delivered to producing department ready for use. It embraces the following:

Purchase Price of Material

Market replacement cost at which material can be purchased should be used for all costs, serving as a basis for selling prices.

Price at which raw material has been acquired shall be used as the basis for determining actual cost of production.

Handling

Freight or other charges for delivery to plant Purchasing—salaries and expense		To be added to raw material purchase price at a definite cost per 100 pounds or gallons
Receiving Storage Handling	labor and expense	

Shrinkage and handling losses to be added as a standard percentage for each individual item.

Manufacturing Cost. Complete cost of processing resulting in product ready for sale. It embraces:

Direct Manufacturing Cost. All labor and expense employed in actual production of the products.

Labor

Productive	Mixing Grinding	Thinning Shading	of Paints and Lacquers	Assessed to individual product to cover time employed
	Cooking Thinning	Filtering Storage Blending	of Varnishes	

Non-productive	Janitors Mill Dressers	Elevator Operator Non-productive Workmen	To be treated as department burden and added to productive labor on a percentage basis
Department Supervision			
Salaries	Foremen Department Clerks		
Expense	Light, Heat, Telephone, etc. Sundry Dept. Expense		

Power *Fuel* for varnish kettle fires *Maintenance* of machinery and equipment	Assessed against individual product at a standard cost per hour for time mill or kettle is occupied by individual product

Overhead.

General Factory Expenses Supplies and general expense not chargeable to individual departments. *Superintendence* Salaries: Superintendent Laboratory and technical men employed in control Factory Office Clerks Watchmen Expense: Factory Office Laboratory *Factory Administration* Maintenance of Buildings Factory Administration Expenses Laboratory Research for development of new products Taxes on factory land, buildings, equipment, raw materials, and manufactured products Insurance Expense Insurance on buildings, equipment. raw materials, and manufactured products Liability Insurance Social Security Tax Employees' Welfare Depreciation on buildings, machinery and equipment; to be figured on basis allowed by the U.S. Treasury, Income Tax Division Rent on factory buildings and land rented	To be treated as general burden and added to direct manufacturing cost on a percentage basis or at a fixed rate per unit of product. To be based on normal capacity operation of plant

Royalties

Royalty paid for formula or process to be included in cost of individual item.

Bulk Cost. Comprises all preceding elements.

Package and Packaging Cost

Containers Labels Packing Cases Filling, Closing and Labeling Labor & Exp. Packing and Stockkeeping Labor & Expense	To be added to bulk cost at standard cost for each size package

Factory Filled Cost. Comprises all preceding elements to manufacture a product ready for sale.

Full Selling Cost. Embraces Factory Filled Cost and

Selling, Distributing, and Administrative Expense

Sales Office and Mangmt. Salaries & Exp. Representatives' Salaries, Commission and Expense Stationery, Office Supplies, Stamps, etc. Allowance and Adjustments Warehouse Salaries and Expense Branch Warehouse Rent, Taxes & Insurance Advertising Salaries and Expense Transportation On Shipment to Warehouses Cartage Cash Discounts on Accounts Receivable Bad Debts Charge Off Sales Administration Expense Technical Service for Consumers	To be included in cost on basis of a per cent added to complete factory cost

Selling Price. Price per gallon or pound of product offered to the trade as a list price subject to discount to dealers and jobbers or as a net price to consumers. All *prices* to be based on *full selling cost.* No *profit* is realized until all *selling expense* has been provided for.

In the foregoing comprehensive chart and outline are several terms which may well be amplified. They are defined in the following paragraphs:

Raw Material Cost

When calculating cost to serve as a basis for selling price, the manufacturer should figure raw material at the price at which it can be purchased for the prospective business. Obviously, such market replacement cost is the soundest basis for safeguarding profits of a going concern.

The actual cost of product made should, of course, be calculated at the cost at which material was acquired. This figure may be quite different from the replacement market, but it does indicate the actual expenditure for product sold.

The cost to purchase, store, and handle raw material from the time it is ordered and received until it is put into the manufacturing process amounts to 1½ to 3 per cent of the cost of material. This may be included at a definite rate per 100 lb or gal or, for simplicity, may be added to delivered purchase price as a percentage.

Shrinkage and handling losses, due to drying out, sifting, leakage, evaporation, etc., depend on the character of the material and quantity handled. This loss averages from 1 to 5 per cent.

Raw Material Identification Code

To facilitate handling of raw material, it is most practical to establish a code indicating individual raw materials, preferably by number. A simple code numbering system can be devised by assembling raw materials into groups of similar character, as, for example: white pigments, inert pigments, coloring pigments, iron oxides, etc., varnish resins, nonvolatile oils, volatile thinners, etc. Next a number should be assigned to each group, and then the members of the group should be numbered in the order of their importance. Thus sufficient numbers for additional raw materials within each group are provided, avoiding confusion of numbers in the future. Note the following examples:

Group 1.	White Pigments	Group 2.	Inert Pigments
1- 1	White lead carbonate	2-1	Asbestine, magnesium silicate
1- 2	Basic lead sulphate	2-2	Barytes
1- 3	Leaded zinc 35%	2-3	Whiting
1-10	Titanium dioxide	2-4	China clay
1-15	Titanium calcium pigment		

Incoming packages of material should immediately be clearly marked with the code number and space provided in the storage room reserved for each individual material number. This code should be used in all handling of raw material stock records, requisitions for further supplies, etc. Cost records should be kept by code numbers. Formulas should be written up in code. It has been found that code numbers greatly facilitate and simplify, also reduce, the amount of clerical work in recording and accounting for the movement of raw materials. They aid in avoiding errors in handling materials.

Handling

Stock limits should be provided to control the amount of material in stock, and the quantity to be ordered at one time. New supplies should be ordered in minimum quantity procurable at the most favorable price. Orders are to be placed in time so that new supplies may arrive before existing stock is exhausted. To maintain minimum investment in raw materials it usually is found practicable for the raw material stock-keeper to take an inventory of all raw material weekly and place requisitions for necessary purchases to replenish the supply.

Special attention should be given to slow-moving or dormant stock items, and every effort made to use them up promptly. A large amount of more or less useless material can accumulate in a short time, unless this problem has intelligent attention and close supervision. Raw material stores should be under the care of a storekeeper who will deliver to the consuming departments on their requisition. Obviously, to re-

duce handling expense, supplies should be stored adjacent to, but not in, the consuming department. It has been found that control of raw material stock is not so dependable if it is handled by the man who uses it.

Formula Yield and Material Cost

The bulk or yield of a formula can best be determined by actual weight or measurement of raw material put into the process and by a count of filled packages or an actual measurement of bulk material produced.

To calculate the theoretical yield of the formula, the manufacturer is referred to publications of the *Scientific Section* of the National Paint, Varnish, and Lacquer Association: *Circular* 709, "Petroleum Thinner Index," Sept. 1945; *Circular* 722, "Pigment Index of 1947," Supplement 11, Nov., 1949; *Circular* 730, "Drying Oils Index," March, 1949; *Circular* 737, "Driers, Plasticizers, and Chemical Specialties Index," April, 1950; *Circular* 738, "Resin Index," May, 1950.

It should be emphasized that many types of pigments vary over a wide range in their bulking values. Among these are iron oxides, both natural and precipitated, chrome greens, yellows and oranges, all the pure and reduced toners, leaded zinc oxides, carbon, lamp and bone blacks, and many others. The following data represent average values for some of these items, although individual members may vary considerably. Hence, when in doubt, the formulator is advised to request the manufacturer of such pigment to supply the proper bulking value or determine by careful test the exact bulking value of the pigment used.

These data will enable the formulator to estimate the number of gallons of paint, varnish, or lacquer resulting from the ingredients used. When making due allowance for manufacturing losses, he can obtain a very accurate determination of the yield of any given formula.

Manufacturing Losses and Material Cost

All the following elements must be considered when the figure for dividing into the complete cost of raw material used in the formula is being set to determine the material cost per gallon or pound of the product.

A considerable amount of raw material is lost in the process of manufacture. When material is put into the mix, some may be spilled or may adhere to the container. During the operation of mixing and grinding, evaporation occurs in volatile liquids. A certain amount of finished product adheres to the mixers, mills, etc., or is strained out as skins when the material is filled.

REPRESENTATIVE RAW MATERIALS

Pigments	Specific Gravity	Pounds per Solid Gallon	Gallons Bulked per Pound
White			
Titanium dioxide, anatase	3.88	32.32	0.03094
Titanium dioxide, rutile	4.20	34.99	0.02858
Titanium calcium pigment	3.25	27.07	0.03694
Zinc oxide, lead free	5.61	46.73	0.02140
Zinc oxide, acicular	5.59	46.56	0.02148
Zinc oxide, 35% leaded	5.92	49.31	0.02028
Zinc oxide, 50% leaded	5.96	49.65	0.02014
Basic carbonate white lead	6.70	55.81	0.01792
Basic sulphate white lead	6.40	53.31	0.01876
Lithopone	4.30	35.82	0.02792
Antimony oxide	5.73	47.73	0.02095
Extender Type			
China clay	2.60	21.66	0.04617
Barytes	4.40	36.65	0.02729
Whiting	2.71	22.57	0.04431
Magnesium silicate (asbestine)	2.85	23.74	0.04212
Silica	2.65	22.07	0.04531
Black			
Carbon black	1.81	15.08	0.06631
Lamp black	1.78	14.83	0.06743
Iron oxide black	4.95	41.23	0.02425
Flake graphite	2.29	19.08	0.05241
Iron Oxides			
Venetian red	3.85	32.07	0.03118
Dark red oxide	5.00	41.65	0.02401
Dark orange iron oxide	4.09	34.07	0.02935
Brown iron oxide	4.15	34.57	0.02893
Miscellaneous			
C. P. Chrome yellow, L	5.57	46.40	0.02155
C. P. Chrome orange	6.87	57.23	0.01747
C. P. Molybdate orange	5.32	44.32	0.02265
C. P. Zinc chromate	3.54	29.49	0.03391
C. P. Chrome green, D	2.57	21.41	0.04671
Chromium oxide green	5.09	42.40	0.02358
Phthalocyanine green	1.97	16.41	0.06094
C. P. Iron blue	1.85	15.41	0.06489
Ultramarine blue	2.32	19.33	0.05173
Phthalocyanine blue	1.64	13.66	0.07321
Red lead, 97%	8.90	74.14	0.01349
Toluidine red	1.40	11.66	0.08576
Para red	1.49	12.41	0.08060
Graphic red	1.74	14.49	0.06901
Maroon toner	2.10	17.49	0.05718
Aluminum powder	2.55	21.24	0.04708
Aluminum paste	1.47	12.25	0.08163

REPRESENTATIVE RAW MATERIALS (*Continued*)

Liquids	Specific Gravity	Pounds per Gallon*
Drying Oils		
Linseed		
Raw	0.930–0.936	
Refined	0.930–0.936	
Boiled (heat-bodied)	0.937–0.940	
Dehydrated Castor Oil		
Dehydrol, light-body	0.945–0.950	
Dehydrol, heavy-body	0.953–0.958	
Oiticica Oil	0.970–0.975	
Tung Oil		
Raw	0.940–0.943	
Tall Oil		
Crude	0.970–0.990	
Soybean Oil		
Clarified	0.924	
Alkali-refined	0.924–0.928	
Bodied	0.942–0.945	
Fish Oil		
Light cold-pressed sardine	0.927–0.935	
Heat-bodied sardine	0.970–0.990	
Thinners and Solvents		
Turpentine	0.864	
V M & P Naphtha	0.747	
Mineral spirits	0.786	
Heavy mineral spirits	0.804	
Solvesso Number 1	0.833	
Toluol	0.870	
Solvent naphtha	0.875	
Specially denatured alcohol	0.815	
Butyl alcohol	0.809	
Butyl acetate	0.870	
Ethyl acetate	0.884	
Driers		
Liquid, lead naphthenate		9.57
Liquid, manganese naphthenate		7.95
Liquid, cobalt naphthenate		7.93
Liquid, zinc octoate		7.4
Resins		
Alkyd		
Phthalic alkyd, oil modified		8.00
Phthalic alkyd non-dry, oil modified		8.20
Alkyd, non-phthalic		8.75
Alkyd, resin-modified		7.49
Urea		
Solution 50% non-volatile		8.30
Melamine		
Solution 50% non-volatile		8.00

* Specific gravity multiplied by $8\frac{1}{3}$.

REPRESENTATIVE RAW MATERIALS (*Continued*)

Resins (*Continued*)	Specific Gravity	Pounds per Gallon	Gallons per 100 Pounds
Vinyl			
Liquid 35% non-volatile		7.52	
Solid	1.36		
Coumarone-Indene Resins			
60% non-volatile		8.04	
Petroleum resins, solid	1.09–1.12		
Maleic solid	1.10		
Phenolics			
Pure	1.21		
Modified	1.10		
Ester gum, solid	1.07		
Rosin	1.07		
Natural resins			
Fine melt pale Congo			11.50
No. 1 Pale East India nubs			11.50
Singapore dammar			11.41
No. 2 Brown kauri			11.56
Orange shellac TN XX			10.80
Miscellaneous			
Phthalic anhydride			7.87
Maleic anhydride			8.00
Pentaerythritol			8.70
Glycerine		10.49	
Para tertiary butyl phenol			11.80
Cellulose nitrate			
RS, ¼ Sec.			7.04
SS, 5–6 Sec.			7.04
Cellulose acetate			
Flake			9.00
Ethyl cellulose			
High-viscosity			10.50

The amount of such loss can, of course, be determined definitely in regular factory production by actual measurement of volume or weight of raw material put into the process compared with the quantity of finished product filled into containers. Obviously, however, it is necessary to forecast such results when estimating the cost of a product for prospective business.

This loss can be estimated by the experience resulting from similar products formerly manufactured. Such a loss on various products may be found to be from 1 to 5 or 6 per cent, depending on the character of the product and the size of the batch manufactured.

In the production of varnishes much of the bulk is lost in the cooking process. A considerable volume of impurities is taken out when

the product is filtered. There is a further loss of sediment and evaporation in storage tanks. These losses depend on the formula, manufacturing process, and type of equipment used and on the quantity produced in a continuous run.

The yield of any given varnish formula depends on the character of the varnish and also on the method of manufacture and the efficiency of the plant. The theoretical yield may be calculated roughly from data covering the yield of each ingredient. No reliable figure is obtainable, however, without the actual manufacture of the formula or comparison with a similar one.

The gross yield may be determined approximately by calculating that 100 lb of resin will yield 8 to 10 gal, depending on the nature of the gum and the melt.

Through a long series of careful tests by many manufacturers, it has been found that much of the material put into the process is lost by exaporation or through sediment filtered from the finished product.

The loss incurred by cooking of oils averages 2 to 3 per cent. An average of 2 to 4 per cent is lost from the turpentine or naphtha thinner used in reducing the varnish. No yield is expected from driers such as lead, manganese, cobalt, etc., nor from lime. Filtering losses are from 1 to 2 per cent.

Manufacturing Cost

Direct manufacturing cost embraces all labor and expense employed in the actual production of the product.

Productive or direct labor is the labor employed in the actual production of a product and can be accounted for in a most practical way by assessing it to the individual product or group of products being made.

Non-productive or indirect labor is employed in general work not resulting directly in the production of manufactured products. It cannot be assessed directly to a product or group.

Power purchased from outside sources or generated in the local power plant and maintenance of mills and mixing machinery are directly chargeable to the product or group on the basis of the time the machinery is occupied. A standard cost per hour for each mill may be set by accounting, which will accumulate the cost of power used and expense to repair and keep machinery in order, this sum to be divided by the number of hours the line of mills is operated.

Fuel for varnish fires can be best included in the manufacturing expense of a product on the basis of time occupied. Cost per kettle hour is determined by accounting covering the fuel used divided by the number of hours the fires are operated.

Overhead

The overhead in a factory comprises a large group of fixed charges and other expenses which cannot be assessed directly against any one product. Also, these expenditures continue all the time and cannot be adjusted in keeping with the volume of production. These are enumerated fully in the foregoing outline.

Taxes included should be only those on property value. Income tax, capital stock tax, excess profits, etc., should not be considered as factory overhead.

Depreciation charged into the cost of production should be that allowed by the U. S. Treasury Income Tax Division. The average annual charge has been found to be approximately:

Buildings	2– 5% of original value.
Machinery	3–10% of original value.
Furniture & fixtures	10–20% of original value.

The most satisfactory way to absorb such overhead fixed charges, superintendence, general factory expense, etc., into the cost of manufactured products is to spread it on the basis of normal capacity operation of the plant. That is, to consider approximately 80 per cent of rated full capacity production as the volume of product to take up all expenditure.

This is generally accepted as the best modern accounting practice. Any expenditure not absorbed on this basis is a direct charge to profit and loss as the cost of idle plant.

This plan has the distinct advantage of assessing against the product only its fair share of such general expenditure at all times. Thus, considering overhead expense at a normal rate keeps the cost of products more in line with the possible competitor whose plant may be fully occupied. Obviously, excessive overhead assessed against a product at times when production is low may have the effect of causing prices to be advanced, probably resulting in further serious loss of business.

Bulk Cost

Bulk cost embraces all expenditure for raw material and complete manufacturing expense, labor, and overhead to make the product in bulk prior to filling into containers for sale.

Package and Packaging Cost

Package and packaging cost represent a large and variable feature of the cost of finished product. A schedule of standard costs for pack-

ages of all sizes should be prepared, covering cost of containers, labels, cases, etc., and the filling, handling, labeling, packing, etc., plus labor and expense. All these are required to fill, finish, and warehouse the product and prepare it for shipment to the customer.

Filled Factory Cost

Filled factory cost embraces the complete cost of material in bulk with further addition to cover package, etc. Thus it includes all factory expenditure for the product ready for shipment to the trade.

Full Selling Cost

The expenditure incurred in marketing the product must be covered by the selling price before any profit results. These items of selling and distributing expense, enumerated in the outline, can be included in the cost most simply by a schedule of percentages, providing for different classes of business. Large volume sales or contracts obviously cost less to sell than do small orders. A careful study indicates that in many companies the selling and distributing expense averages about as follows when compared to the complete factory filled cost of the product:

Bids for large volume business	10 to 15% of factory cost.
Contracts for large volume	15 to 20% of factory cost.
General consumers' business	20 to 25% of factory cost.
Trade sales	30 to 50% of factory cost.

This percentage should be added before setting the selling price.

Selling Price

The selling price of any product should give fullest consideration to:

Complete cost to manufacture.
Cost of selling and distributing the individual product.
Volume of business in prospect.
Anticipated profit.
Value of product to the consumer.
Competitive prices on comparable product.
Credit risk of the account.
Technical service required by consumer.

Profit

Profit should be considered as a per cent of selling price rather than as a per cent in relation to cost. The amount of the sale is the more tangible basis, and the per cent of profit is more conservatively expressed.

TYPICAL COSTS ILLUSTRATING APPLICATION OF FOREGOING PRINCIPLES

The illustrations on the following pages apply the principles outlined in the foregoing paragraphs.

Starting with the market price of raw material, the percentage to cover loss or shrinkage and the handling expense are added to determine the unit cost of raw material in the producing department. Formula yield is estimated, using data of bulking value, etc., as mentioned. The procedure is then carried on through the successive steps, resulting in a filled factory cost.

REPRESENTATIVE MARKET PRICES

	Oil Paint & Drug Rep. Market Aug., 1950	Shrinkage per cent	Handling Expense	Figuring Cost per Pound or Gallon
Titanium dioxide	$0.195	½	$0.10/cwt	$0.197
Zinc oxide	.1575	½	.10/cwt	.159
White lead	.1625	½	.10/cwt	.164
Asbestine	23.00/ton	½	.10/cwt	.015
Zinc yellow	.21	½	.10/cwt	.212
Raw sienna	.10½	½	.10/cwt	.107
Raw linseed oil (wt. 7.76)	.178	1	.50/100 gal	1.40 gal
Refined linseed oil (wt. 7.76)	.198	1	.50/100 gal	1.557 gal
Mineral spirits	.15	3	.50/100 gal	.173 gal
Tung oil (wt. 7.83)	.255	1	.50/100 gal	2.014 gal
Alkyd resin 52-R-13 Gr. 1	.1975	2	.10/cwt	.202
Dipentene	.50	2	.50/100 gal	.515 gal
Phenolic resin	.35½	2	.10/cwt	.362

EXTERIOR OIL PAINT WHITE
Federal Specification TT-P-40 Type 1 Class A

Specification: Pigment, 66%		Vehicle, 34%.	
Titanium dioxide	14%	Linseed oil	65%
Zinc oxide	30%	Drier and thinner	35%
White lead	41%		100%
Extenders	15%		
	100%		

Weight: 15.75 lb per gallon

	Pounds	Yield in Gallons	Unit Cost	Total Cost
Pigment, 66%				
Titanium dioxide	140	4.34	0.197 per lb	$27.58
Zinc oxide	300	6.42	.159 per lb	47.70
White lead	410	7.26	.164 per lb	67.24
Asbestine	150	6.45	.015 per lb	2.25
Vehicle, 34%				
Raw linseed oil	300	38.81	1.40 per gal	54.33
Bodied linseed oil	35	4.34	1.85 per gal	8.03
Mineral spirits	160	24.61	0.173 per gal	4.26
Driers	20	2.82	0.75 per gal	2.12
		95.05		213.51
Manufacturing loss, 2%				
Net yield (98%)			93.15 gal	
Material cost per gallon				$2.292
Manufacturing cost per gallon				0.12
Bulk cost per gallon				2.412
Complete package cost per gallon (5-gal cans)				0.18
Factory cost in package				2.592

ZINC CHROMATE PRIMER
Joint Army-Navy Specification JAN-P-735

	Pounds	Yield in Gallons	Unit Cost	Total Cost
Specification and Formula				
Pigment				
Zinc yellow TT-Z-415	270	9.15	0.212 per lb	$57.24
Titanium dioxide TT-T-425 Type II	75	2.32	.197 per lb	14.78
Zinc oxide TT-Z-301	95	2.03	.159 per lb	15.11
Raw sienna TT-S-346	25	0.92	.107 per lb	2.68
Magnesium silicate 52-M-2A or B	75	3.15	.015 per lb	1.13
Aluminum stearate 52-A-12	6	0.66	.333 per lb	2.00
Vehicle				
Alkyd resin solution 52-R-13 Gr. 1	345	43.12	0.202 per lb	69.69
Dipentene TT-D-376	22	3.10	.515 per gal	1.60
Paint thinner TT-T-291 Gr. 1	235	36.20	.173 per gal	6.26
Lead naphthenate drier 52-D-7	12	1.25	.212 per lb	2.54
Cobalt naphthenate drier 52-D-7	1.2	.15	.39 per lb	0.47
Manganese naphthenate drier 52-D-7	1.2	.15	.239 per lb	0.29
		102.20		173.79
Manufacturing loss, 2%				
Net yield (98%)			100.16 gal	
Material cost per gallon				$1.735
Manufacturing cost per gallon				0.12
Bulk cost per gallon				1.835
Complete package cost per gal (55-gal drums)				0.095
Factory cost in packages				1.930

ALKYD-PHENOLIC MIXING VARNISH
Navy Specification 52-V-18a

Specification and Formula	Pounds	Yield in Gallons	Unit Cost	Total Cost
Resin				
Phenolic resin	100	11.2	0.362	$36.20
Vehicle				
Alkali-refined linseed oil	96.2	12.5	1.557	19.46
Tung oil	97.50	12.5	2.014	25.18
Petroleum spirits (thinned to 60% solids)	196	30.2	0.173	5.22
		66.40		86.06
Manufacturing loss, 2%				
Net yield (98%)			65.07 gal	
Material cost per gallon				$1.323
Manufacturing cost per gallon				0.08
Bulk cost per gallon				1.403
Complete package cost per gal (5-gal cans)				0.18
Factory cost in packages				1.583

Factory cost accounting, according to R. C. Stark, will provide the following information for plant control and the guidance of operating management:

1. A complete comprehensive check of raw materials and containers with particular emphasis on economies in purchasing, handling, and shrinkage.
2. Data on manufacturing costs with relation to methods of manufacture, type of equipment used, excess cost of small orders, reduction of loss or shrinkage in manufacture, and similar facts.
3. Regular departmental cost analysis reports on labor and expense items for use of supervisors.
4. A complete up-to-date record of all plant machinery and equipment; for instance, depreciation and maintenance information.
5. Regular comparative and cumulative monthly expense analysis reports in sufficient detail for use in supervision and planning by management.
6. Monthly operating profit or loss reports by departments and for the plant as a whole.

ACKNOWLEDGMENT

This chapter has been prepared by W. R. Sieplein of the Sherwin-Williams Company who has served the paint, varnish, and lacquer industry in an advisory capacity on the subject of cost accounting for many years; his continued interest in our behalf is sincerely appreciated by the editors.

REFERENCES

Gardner, H. A., "Physical and Chemical Examination of Paints, Varnishes, Lacquers and Colors," (1939).

Sieplein, W. R., "Cost Figuring Methods," published by the Sherwin-Williams Co., Cleveland, Ohio.

OFFICIAL DIGEST BIBLIOGRAPHY

Bartholomew, H. S., "Uniform Cost Accounting Plan," p. 2 (Jan., 1922).

Blanke, H. B., "Cost System," p. 16 (Dec., 1926).

Buckminster, P. D., "Production and Cost Control," p. 13 (Dec., 1926).

Croal, L. R., "Manufacturing Costs," p. 14 (Jan., 1936).

Ewell, W. H., "Production Costs in the Paint, Varnish, and Lacquer Industry," p. 439 (Oct., 1938).

Finn, G. E., "Determination of Accurate Formula Yields for Pastes, Liquid Paint, and Enamels," p. 294 (June, 1935).

Frishkorn, M. W., "Cost Accounting," p. 821 (Mar., 1932).

Gott, E. L., "Paint and Varnish Factory Costs Especially as Applied to Southern Plants," p. 83 (Mar., 1936).

Hayes, C. M., "Determination of Accurate Formula Yields in the Manufacturing of Nitrocellulose Lacquer," p. 292 (June, 1935).

Kaser, J. O., "Cost of Making Small Batches of Pigmented Materials," p. 866 (Apr., 1932).
Kaser, J. O., "Use of Costs in Determining Selling Prices and Profits," p. 130 (Apr., 1933).
Kaser, J. O., "Report of the Cost Accounting Committee (1936)," p. 122 (Apr., 1937).
Kaser, J. O., "Report of the Cost Accounting Committee (1937)," p. 363 (Dec., 1937).
Katinsky, H., "Man and Mill Hours," p. 300 (June, 1940).
Keiller, A. S., "Factory and Cost Accounting," p. 48 (Feb., 1936).
Lade, M. W., "Present-Day Costs," p. 349 (Dec., 1936).
McNerney, F. M., "Cost Accounting," p. 296 (June, 1940).
Neuburger, R., "Distribution and Profits," p. 335 (Dec., 1933).
Place, T. H., "Distribution of Overhead Costs by Departments," p. 12 (Jan., 1933).
Royer, J. A., "Cost Accounting," p. 769 (Feb., 1932).
Sieplein, W. R., "Digest of the Cost Figuring Problem," p. 168 (Apr., 1938).
Sieplein, W. R., "Uniform Cost Accounting," p. 134 (Apr., 1936).
Sondhaus, C. H., "Cost Accounting in a Paint Factory," p. 70 (Mar., 1930).
Stark, R. C., "Cost Accounting as an Aid to Plant Management," p. 478 (Apr., 1935).
Stark, R. C., "Production–Supervision and Costs," p. 297 (May, 1944).
Stephan, A. C., "Manufacturing Costs," p. 574 (Sept., 1931).
Storey, E. W, "Cost Accounting," p. 9 (Nov., 1923).

ADDITIONAL FEDERATION OF PAINT AND VARNISH PRODUCTION CLUB PAPERS

Chicago Club, "Varnish Losses in Weight and Volume," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 3 (Oct., 1939).
Cleveland Club, "Maintenance Cost of Pebble Mills," *NPVLA Sci. Sec. Cir.*, p. 606 (Nov., 1927).
Western New York Club, "Grinding Losses on Stone and Roller Mills," *NPVLA Sci. Sec. Cir.*, p. 372 (Nov., 1935).

CHAPTER 9

RESEARCH, DEVELOPMENT, AND CONTROL

The manufacture of organic coatings is chemical by nature and therefore must employ some form of centralized research and control. Many opportunities exist in this field of applied science for employees who have fundamental knowledge in both chemistry and physics. Usually the technical functions for the company are conducted in the laboratory as a separate department which is directly responsible to the top management. In many plants, however, all operations that are concerned with products are under the direction of the plant manager; the choice between the two systems depends on the ability of the personnel involved and the policies of the company.

If the laboratory is considered a division between production and sales and related to both on an equivalent basis, then the nature of its duties can be classified to substantiate this assumption as follows:

- Industrial research
  - Development of products
  - Engineering improvements
  - Appraisals and costs
- Sales activities
  - Countermatching samples
  - Technical service
  - Bulletins and demonstrations
- Production responsibilities
  - Inspection of raw materials
  - Control of intermediate and finished goods
  - Manufacturing methods

These interrelated functions are primarily concerned with the application of science to the development, production, and sale of merchandise for an acceptable profit on invested capital. The ultimate success of a company depends very much on the ability of the technical staff to perform these functions effectively.

An organizational plan for laboratory work has been described by W. R. Fuller[1] as follows and is shown on *Chart I.*

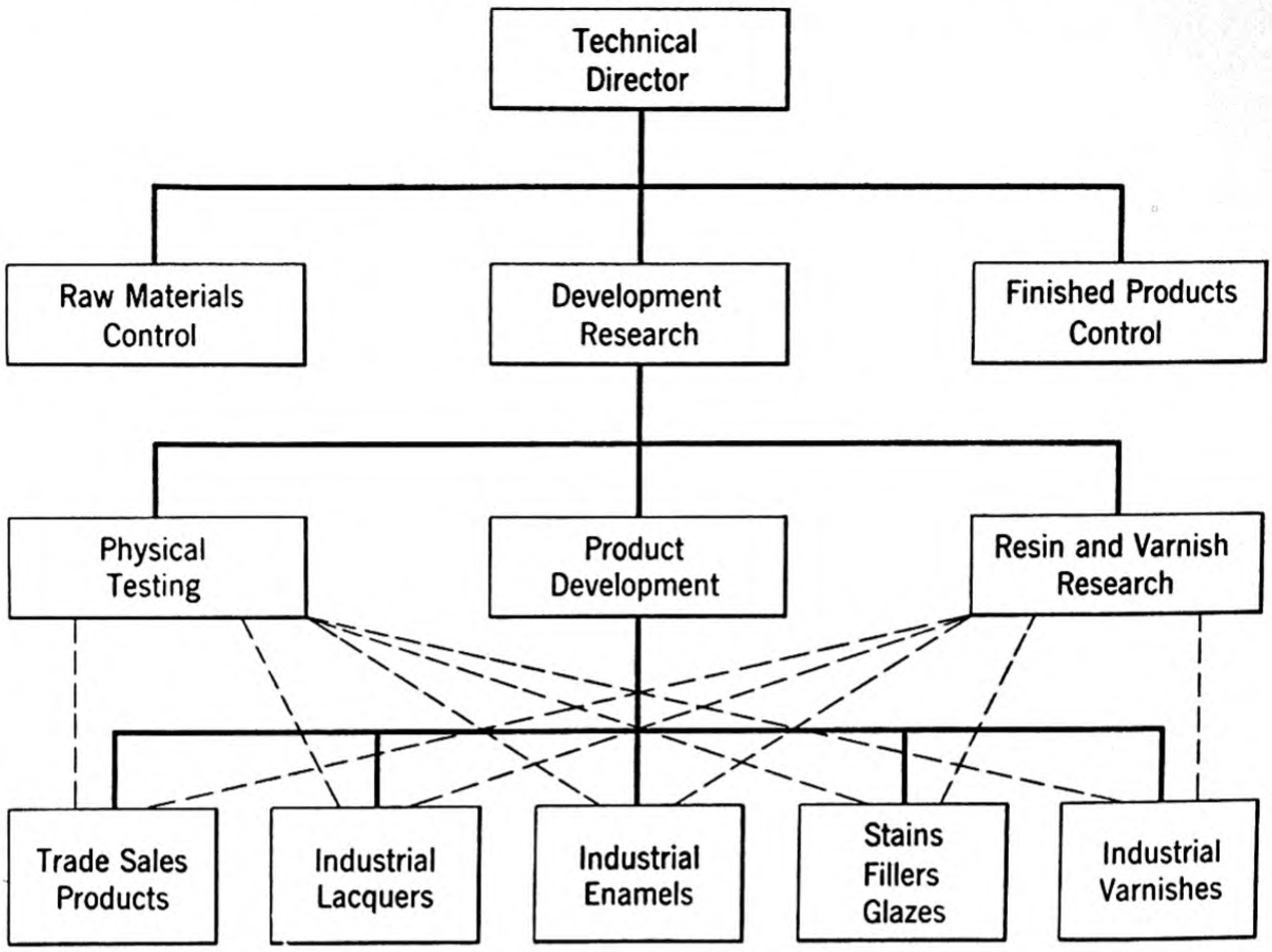


Chart I.

The location and arrangement of laboratories is a phase of administration, since it affects ease of supervision and general efficiency. Unfortunately, in most cases a certain building space is made available for laboratory use and it is just a matter of dividing it in the best manner possible. Discussion is further complicated by wide variance in the size of staffs and the type of work to be done. Even with these limitations it should be feasible to establish a few principles or goals. Finished-product control laboratories should be located in the factories which they serve or adjacent to them. Raw-material control laboratories should be associated with the research and development laboratories, unless these are remote from the factory. Development and research laboratories should be grouped compactly, preferably detached from the factory. One of the main points on which there is likely to be considerable choice is the degree to which the space devoted to development and research is divided into separate rooms. There is a strong case for a separate mill room for grinding and paste-mixing operations. Separate rooms are also clearly indicated for resin and varnish research and for finishing, including baking. When there is considerable physical testing apparatus it is best housed in a separate room. There still remains the general run of the work that is incidental to formulation or development of a wide variety of products. This may be done in one large laboratory or in several smaller laboratories, each devoted to a class of products. While the latter plan may reduce distractions, the former plan saves working space and avoids extensive duplication of apparatus. An ideal arrangement for the large laboratory is to have offices of the supervisors along

one long side, a general service bench for apparatus along the opposite side, and, running crosswise between them, double working benches assigned to the various classes of products.

It is natural to turn from the laboratories to the equipment and apparatus in them. The first problem that the technical man faces is getting management to authorize the equipment that he needs, although the attitude of management becomes steadily more liberal. Since the largest item of laboratory expense is salaries, it is only good business to provide the equipment that will yield the greatest return from the salary expenditure. Ever higher standards of performance for finished products demand more precise testing methods, which mean better apparatus. Aside from its direct utility, good equipment helps to attract and hold good chemists and inspires confidence in salesmen and customers alike. Beyond doubt an increasing number of technical directors will be granted the equipment they want, provided that their requests are judicious and well presented. Specific kinds of apparatus will not be discussed. It is, however, in order to point out that apparatus deserves maintenance and especially that all viscosity cups, glossmeters, and cryptometers in a technical department should be checked at least once a year for deviation of individual instruments.

Research and Development

Basic research in the field of chemical coatings is carried on by the larger manufacturers, suppliers of the industry, and institutions of higher learning, whereas the smaller plants confine their efforts to the adaptation of new materials and processes rather than the academic study of the physical and chemical properties of substances and the preparation of new compounds.

Nevertheless, the scope of applied research includes the evaluation and use with modification if necessary of film-forming materials by staff members who have had broad experience in the formulation of coatings and have the creative ability to utilize their properties for specific requirements.

The unlimited possibilities which high polymers possess provide a base for profitable research in the field of protective and decorative coatings. Color and the desirable refinements for appearance and application are additional considerations for product development.

Equally important to management but often neglected is the study of improved methods of processing and handling of products. The heat treatment of oils and resins, the dispersion of pigments in vehicles, and the thinning and tinting of batches, all present engineering problems for the laboratory staff. The background and training of personnel should be such that efficient plant procedure is recognized and appreciated when new products are developed.

The evaluation of new machinery and the effective use of old equip-

ment are joint responsibilities which the laboratory shares with the production department. It may involve the size of batches, temperature cycles in cooking vehicles, optimum conditions for mixing and grinding, agitation during thinning and tinting, the storage of materials, or manufacturing losses.

Development factors are explained by D. B. Keyes[2] as follows:

> The future of any company especially in the process industries, such as paint and varnish, depends largely on the value and the accuracy of the predictions made by members of the organization and particularly on those predictions concerning new products.
>
> It is well known that a company lives or dies on its growth factor. It is impossible for a company to remain stationary and still exist because sooner or later its activities will diminish, its profits will be reduced and it will become a losing proposition. This is the reason why predictions are so important. They are based on the evaluation of data; statistics; technical and economic facts, both real and imaginary; assumptions, rumors, and that mysterious something known as the sixth sense of the management.
>
> Oftentimes, in the process industries no really accurate predictions on a new product or on the sale of a product can be made beyond a relatively few years. This is one of the reasons why it is essential for a company to be constantly producing profitable new products which will pay for the investment with a reasonable return and can be dropped when the return is unsatisfactory. The paint and varnish industry, therefore, is dynamic. Its security lies only in progress.
>
> Management, research, production and sales look at an appraisal from the standpoint of three figures: what is the capital cost to complete the project, including the building of a commercial plant; what is the probable profit on this investment; and how long can it be estimated that this probable profit will be obtained. The starting date of production is, of course, important.
>
> In order to make the predictions or to obtain the three figures mentioned, the study is usually based on three primary factors: a study of raw materials, the process or operation, and the product.
>
> A general outline[3] of an industrial process development is shown in the chart below. There is nothing novel about this chart. It represents the common subject matter of the usual chemical development appraisal. The complexity and improbability of obtaining answers to all the questions indicated is apparent. No discussion is necessary because everyone recognizes the importance of all the factors given.
>
> It is top management's business to select which projects it can afford to develop after reviewing the appraisals. These men determine the rate of growth of the company and the lines along which it grows. Their task is infinitely more simple if they are furnished with accurate appraisals.

OUTLINE OF THE APPRAISAL OF AN INDUSTRIAL PROCESS DEVELOPMENT*

(Capital Cost, Probable Profit, and Length of Life)

by

D. B. Keyes

I. Raw Materials

A. Past, present and future cost
B. Extent and adequacy of present and future source
   1. Number of producers
   2. Location of source
   3. Collection and transportation
   4. Seasonal production
   5. Waste material
C. Specifications and character of impurities
D. Container or package
E. Storage
F. Patents
   1. Manufacture
   2. Use
G. Legal Requirements
H. Tax, Tariff, etc.
I. Safety Factors
J. Possible future developments

II. Process or Operation

A. Chemical processes
   1. Equilibrium (Static or Dynamic)
      a. Yields
      b. Conversions
      c. Material balances
      d. Energy balances
   2. Rates (Time)
   3. Character of Equipment
   4. Labor requirements
   5. Power requirements
B. Physical Operations (Similar to above)
C. Production rate (optimum)
D. Patents (Manufacture)
E. Legal Production Matters
F. Safety Factors
G. Capital Cost
H. Operation Cost
I. Possible future developments

III. Product (Old and New, Including By-products)

A. Character of the product
   1. Chemical Properties
   2. Physical Properties
   3. Specifications and Impurities
   4. Containers or package
   5. Storage
   6. Safety Factors
B. Market (Past, present and future use)
   1. Uses
   2. Capacity
   3. Price Range
C. Patents
   1. Product Patents
   2. Use Patents
D. Trade Marks
E. Legal Requirements
F. Tax, Tariff, etc.
G. Sales Service Required
H. Advertising
I. Character of the Customers
   1. Number
   2. Location
   3. Size
   4. Length of "Life"
   5. Trade agreements
J. Competitive Products
K. Character of Competitors (Same as for Customers)
L. Possible future developments

Note: Factors to be considered when evaluating a patent:
1. Extent of coverage by the claims
2. Exactness and completeness of the specifications
3. Validation by a court

* *Chem. Eng. News,* p. 489, Vol. 27, No. 8, Feb. 21, 1949.

Sales Activities

New demands from consumers make it necessary that established lines be continually improved. Regular examinations of standard formulations for possible improvements in brushing, color, color retention, washability, and other properties are necessary. The availability of materials and cost limitations necessitate frequent reformulation of products and offer possibilities for the improvement of product characteristics. Regular checks of leading competitive items will serve to keep established lines in tune with competition.

It is essential that the laboratory keep in close touch with the sales department to learn what types of finishes are desired by the consumer. The regular examination of new raw materials should indicate the possibilities which exist for fewer coats, easier application, better adhesion, improved durability, and the development of coatings to replace or enhance other products.

> While trade sales development projects are likely to originate in the technical department, it is safe to say that a great majority of industrial problems come from the sales department, usually much too fast. Most of these problems are quick, easy jobs: a standard type of formulation with some minor adjustment, perhaps nothing more than a special color or a different sheen. Along with these are a few tough ones, and it is primarily these tough ones that determine how the technical department rates. Any alert technical department will at times see possibilities in the utilization of new raw materials and a chance to give the sales department something good that it has not even asked for. The rub is how to find the time to do these things. There are two possible approaches and both must be employed to even come close to the objective.
>
> The first approach involves the sales department. It should be able to understand that there is a limit to the capacity of a given technical organization; that too much work means either poor work or slow work; that either means poor results in sales; that the sales department will profit by applying vigorous screening to the requests submitted and accepting no more than can be handled promptly. In making this selection considerable weight should be given to the nature of the problem, whether it falls within the field which the company has staked out for itself and in which it has experience. The laboratory can help in this approach by returning to the sales department those requests which are accompanied with wholly inadequate information and by questioning those jobs which raise doubts on other points.
>
> The second approach is strictly one of internal laboratory organization. The group of men working on a single class of products, such as synthetic enamels and undercoats, is split into two groups. The smaller group, usually one or two, is detached from run of mill jobs and confined to important, major jobs that extend over a period of months and frequently involve the utilization of new raw materials.

This group should have only one or two problems at a time. As soon as a problem is brought to the stage of satisfactory production use, it should be turned over to another group.

Most requests for development or formulation of industrial products originate with a salesman, go to the sales office, thence to the laboratory. After the laboratory has completed its work, a report must go back to the saleman by the reverse route. All paint manufacturers have systems designed to facilitate this procedure. While no single system can be best for all companies, one system will be described that is very complete and it can be simplified if desired. Discussion of this system is relevant to the subject because it keeps the technical director automatically informed on the work of the product development groups and provides his most effective instrument for supervision.

This system is built around a single form which serves several purposes. One side of this form is a Request for Laboratory Work, as shown by *Chart II*. The plan requires that *all* requests for work by the laboratory be made on this form, regardless of how simple the job may be and regardless of whether a competitive sample is involved. Usually this form is made out by a salesman, but at times it may originate with the sales office. After being reviewed and approved by the sales office the form with the sample, if any, is forwarded to the proper supervisor in the development laboratories. If the job is considered especially important or difficult, it is referred to the technical director before going to a supervisor.

When a job is completed a report covering it is made on the other side of the form, which is known as the Laboratory Job Report and shown in *Chart III*. The supervisor forwards this report to the technical director for reviewing and typing. Both sides of the form are typed, copies being made for the sales manager, salesman, technical service department and the supervisor who made the report. The original and all copies are sent to the cost department, where the formula is costed and priced at the standard margin of profit. If the price is out of line with that requested by the salesman, the matter is referred to the sales manager or an assistant for final determination. The various copies are then distributed, the original to the technical director, who has it card indexed according to class of product and filed by number.

This bare outline of procedure makes no attempt to cover details or to answer the numerous questions that may be raised by this form. Without going into these details, a few measures that increase its flexibility and scope will be mentioned. When the space under Remarks is inadequate, the remarks may be continued on a plain sheet of paper, which becomes part of the form. When there is a complicated system, involving a few or more products, it is advantageous for the salesman to describe the complete system on a single form, which is used for reporting only one of the products in the system. The salesman's forms covering the other products need only list the products by name and refer to the key sheet. The sales department may attach a circulation slip to each form before sending it to the laboratory. By affording

REQUEST FOR LABORATORY WORK
(FILLED IN BY SALESMAN)

Customer | Date
Address | Approved by
Person Contacted | Title
Material | Made By
Amount Used Yearly | Shipped in | Price
Used on (A) Article | (B) Material of Which Made
Preparation or Cleaning
Sample Liquid? Panel or Part? | What Was It Taken From? | Has It Been Reduced? How Much?
What Material Goes (A) Under This | (B) Over This?
Applied by | No. of Coats | Thinned | Parts Mat'l To | Parts
Air Drying To Handle | To Rub or Sand | To Recoat | To Pack
Baking Time | Temp | Type of Oven
Time Before Entering Oven | Time to Reach Top Heat | Time at Top Heat | Cooling Time Before Handling
Subsequent Operation
Is Present Finish Satisfactory? (If Not, Why?) | Is Exact Match Required? (Explain)
What Special Properties Required and Tests Made?
Remarks

Quantity Ordered
Ship To | Salesman

Chart II.

LABORATORY JOB REPORT
(FILLED IN BY LAB)

Product | Job No
Customer | Rec'd By Lab.
Type | Date Completed
Shipped To | Date Shipped
Mat'l Cost | Quotation | In | To | Date of Letter

	SAMPLE	OFFSET
Color		
Viscosity		
Wt./Gal		
Solids		
Application		
Reduction		
Drying		
Hiding		
Gloss		
Hardness		
Toughness-Adhesion		
Sanding or Rubbing		

Formula | Remarks

Signed ____________

Chart III.

a record of the time required for each step, bottlenecks are readily located and disagreements avoided. When the sales department mails the report to the salesman, it may attach a form for the salesman to use in reporting on the results obtained by the customer. This report, whether good or bad, should be referred to the technical director and to the responsible supervisor. To obtain the fullest value from the Request for Laboratory Work form, its use should be made comprehensive by extending it to trade sales products and to formulations that originate on laboratory initiative, either trade sales or industrial. In the latter case, the technical director or a supervisor writes out the Request.

Among the benefits of this plan are: (*a*) The salesman receives a single report which gives him the whole story, including salient sales points, (*b*) the sales office has a detailed record of all laboratory work done at its request, (*c*) each development laboratory has a complete file of all jobs it has handled, (*d*) the technical director is kept automatically in touch with the work of the various development laboratories, (*e*) the technical director's index by class of products furnishes daily fingertip assistance in his dealings with the sales department and the laboratory staff.[1]

Technical service and the handling of complaints are also important functions of the laboratory in its relation to the sales department. The sales department must obviously be kept informed of new products, their possibilities, and limitations. Service bulletins and descriptive matter pertaining to products should emanate or at least be reviewed and approved by the technical staff. The extent to which members of the laboratory staff should make field trips depends partly on how well the selling force is organized for handling its own technical service.

As a minimum, the sales department should make definite provision for handling those problems that are essentially application or decoration. There are other problems that pertain largely or mainly to formulation. In these cases it is frequently advantageous for a chemist to call on the customer with the salesman. This affords the chemist a more complete understanding of the problem than can be gained in any other way; it also increases his interest in the specific job and in his work in general. Time spent on trips is not necessarily lost, as it may shorten the time required to satisfy the customer. When substantial new business is involved, the first trip by a chemist preferably should be a survey call before a sample is submitted; the second best time is when the first sample is tested. Too often chemists are called on for post mortem operations. Customers appreciate an intelligent, engineering approach to their problems and are likely to respond to it by whole-hearted cooperation. In designating chemists for service trips the rule should be to send the man in immediate charge of formulation of the products involved, usually a laboratory supervisor. At times circumstances or personalities may justify exception to this rule.[1]

In opinion of H. H. Hopkins:[4] It is a question of philosophy as to whether complaints should be handled by the laboratory or by the plant organization. In small companies, this is probably an academic question but in larger companies, where the technical organization is separate from the operating organization, it is important. Since the plant carries the responsibility for manufacturing the product to a given quality specification, theoretically it should carry the responsibility for investigation and adjustment of the complaint. However, it may be expedient to have the complaint investigated by the laboratory organization in the belief that the laboratory may be more objective in reaching a decision as to the cause and responsibility for the complaint. Incidentally, it is good medicine, . . . to assign responsibility for a complaint to one of the three organizations—operating, technical, or sales. Such responsibility delegation makes the complaint more important and tends to make the individuals in the organization more careful to minimize complaints. The most important thing to be gained by complaint investigations, of course, is the lesson of what went wrong and how it can be prevented from recurring in the future. This should never be lost from sight. Complaints should be regarded as important indicators of how good production is or how good the product is.

Industrial complaints are minimized if production control is closely regulated, and usually they can be traced to materials, surface conditions, or methods of application. The product under investigation, including any additional thinner, should be checked carefully against a standard which is known to be satisfactory. The product, the standard, and the retained sample of the batch should then be applied on identical surfaces under identical conditions. This will determine if the surface or conditions are at fault.

The type of surface treatment used before application of the coating may be the source of trouble.

The methods of application may be directly responsible for the complaint. Spraying equipment should be checked for moisture cleanliness, gun adjustment, and pressure. Baking or force-dry systems should be examined for air circulation within the ovens and for existing time and temperature conditions.

Paint, varnish, and lacquer products are subject to wide variations in viscosities, owing to temperature changes, and atmospheric conditions must be considered when complaints are being investigated, regardless of whether the product is applied by brushing, dipping, or spraying.

Control

The actual control of products involves the inspection of raw materials, the testing of goods in process, and the approval of finished merchandise. These functions normally come under the jurisdiction

of the laboratory which is responsible for standards and methods of test. The procedures employed must be directed to the one objective of maintaining *uniformity* with the least possible effort. Elaborate or academic specifications which may please the chemist or physicist but which consume valuable time should be simplified to avoid interruptions in the normal flow of materials through the plant. The time consumed in testing represents an operating loss that can not be recovered, and unnecessary or excessive delays will automatically increase the capital investment in materials and equipment.

Inspection of Raw Materials. In most instances the supplier of raw materials can be relied upon to furnish uniform products within tolerances which the seller and the buyer have agreed upon. However, mistakes do occur and goods are damaged in transit frequently enough to support a planned inspection program.

A loose-leaf index is convenient for listing each material, manufacturer, supplier, composition, properties, tests, code, number of units, date received, and price.

Standards should be established for all raw materials, and a record of specifications and actual testing methods should be kept as a guide for the inspection laboratory. An adequate system for maintaining standard samples and temporary filing of retains from shipments should be provided.

All incoming materials should be sampled in a prescribed manner by the receiving department and submitted for approval before transfer to storage for factory use.

Uniform quality can generally be established from an examination of the following properties as suggested by P. O. Blackmore.[5]

> Pigments should be checked for masstone, undertone, strength, oil absorption, texture, bleed, fineness, and color stability.
>
> Oils should be checked for iodine number, acid number, refractive index, specific gravity, heat break, color, and clarity.
>
> Solvents should be checked for color, specific gravity, distillation range, evaporation time, residue, sulphur, and solvency. The acidity and non-solvent tolerance of lacquer thinners are also important.
>
> Hard resins should be checked for melting point, acid number, color, and general appearance.
>
> Resin solutions should be checked for specific gravity, viscosity, solids, acid number, color, general appearance, and drying time.

Additional tests may be devised to suit the requirements of individual manufacturers for specific items and abnormal conditions other than those mentioned. For example, the presence of excess moisture and contamination from shipping containers during transit can cause considerable harm unless detected. The purpose of inspection, obviously,

is to provide the production department with a constant supply of raw materials of uniform quality as a safeguard against spoiled batches that otherwise may result from the lack of precautionary measures.

Intermediate or Plant Control. Products in process require continual attention to maintain the standards of quality which have been established. Some of the physical testing must be done in situ. For instance, the operator of a roller mill must be able to test and determine the fineness of grind while the batch is being run. This may be accomplished by rubbing the paste on the blade of a spatula and comparing with a standard or by more accurate methods for measuring draw-downs with fineness gauges.

The tinting of pigmented coatings to match the color of standard samples is the responsibility of the production department. Obviously, color standards, testing equipment, panels, and drying facilities must be provided so that operators can obtain satisfactory results on which to base conclusions with respect to the addition of color.

Similarly, the heat treatment of resins and oils often requires prompt personal judgment during the operation to control the resulting body or viscosity of the batch when thinned. Various testing methods are employed in production to regulate cooking processes, depending on the products and their properties, as described in Chapter 6. However, it is important to remember that technical control by laboratory personnel is not always feasible and that sufficient simple testing to maintain quality is necessary and should be delegated to plant operators.

Production control is a function of the laboratory so far as it involves supervision of first factory batches, technical assistance in making the necessary adjustments, and physical measurements other than for color matching, drying, viscosity, and specific gravity. Naturally, the laboratory must supply the plant with specifications for control tests and manufacturing procedures, as well as standard samples.

The problems of coordinating laboratory and production efforts are best solved by education, largely effected by the establishment of procedures to provide automatically understanding on the part of all concerned of the problems and limitations of product formulas. Unforeseen difficulties disappear quickly where an attitude of cooperation between formulators and operators exists.

Formulation should be on the simplest basis possible with a minimum of control specifications to ensure ready manufacture of the product in the quality desired. Knife-edge formulas are the bane of the production man's existence as the laboratory must recognize.

Finished-Product Control. The testing of finished products twenty-five or thirty years ago was usually done by the production depart-

ment. The trend has been strongly away from this, and today the majority of manufacturers have placed it under the technical department. The following considerations favor this plan: (*a*) the attitude of the tester is not unduly influenced by the desire for large production or meeting shipping schedules; (*b*) a more critical attitude and greated precision of work are likely to be absorbed from the more technical environment; (*c*) the development laboratories have the best understanding of customer requirements and these are more likely to be covered by the control tests.

If control testing is to be done properly it must be handled by men with no other responsibilities and in one or more laboratories that are set apart for this purpose. Efficiency is promoted by concentrating the work in one laboratory or in the smallest number consistent with the factory layout and the products manufactured. This is likely to work out to one control laboratory for resins and primary cooked varnishes and another for all other products.

In determining the tests to be conducted it should be kept in mind that control tests are designed to check uniformity only, not the inherent quality of the formula. Tests should be limited to the fewest and simplest that will assure uniformity. Quite often the tests that serve this purpose best are not those that are most closely related to the method of use. For example, a simple test of the hardness of a rubbing varnish gives a better control of rubbing properties than an actual rubbing test.

All tests should be conducted according to definitely specified methods, not according to the judgment or whim of the tester. The only reasonable assurance that this will be done is to have a testing manual which gives the various methods in detail and prescribes the tests to be conducted on the various standard types of products.

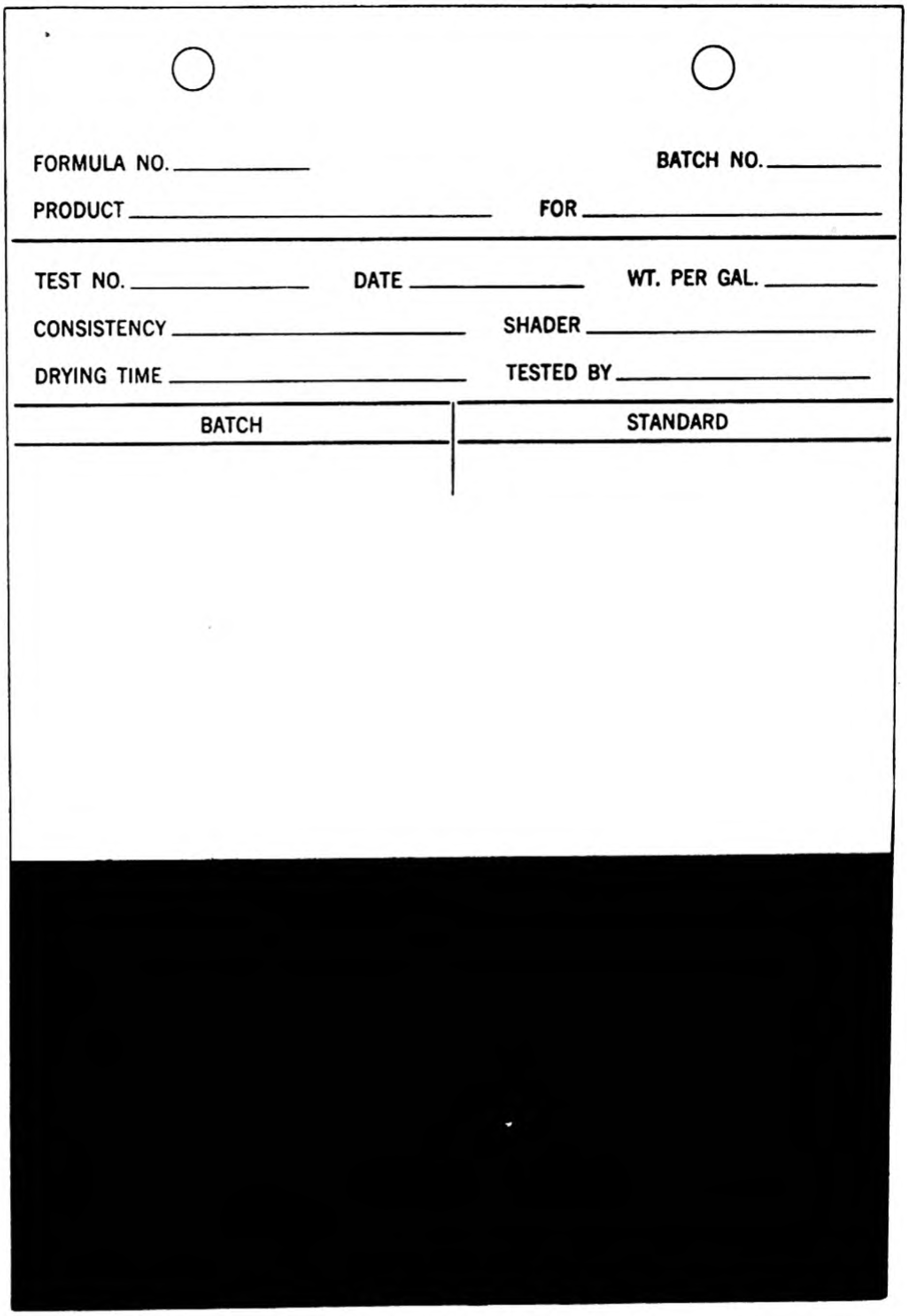
The results of control tests should be completely recorded on special forms or cards, a separate card for each formula. At the top, this card should show the standards for the particular product. The original test record card for each formula should be made out by the formulator of that product, who should indicate the standards. If the product is one that requires special tests, the formulator should describe them on the reverse side of the card.[1]

A typical example of how control records may be kept is shown in Chapter 5.

Pigmented products are normally checked for weight per gallon, consistency or viscosity, color, gloss, fineness of grind, and drying time.

A convenient method for casting a film for testing purposes is by a draw-down of the standard and batch with a Doctor blade on a sized or coated black and white sheet of paper prepared for this purpose as shown on page 240.

It is possible from this sheet to check hiding, color, gloss, set and dry time, and general appearance. When batches are accepted, the draw-down sheet can be filed for future reference.



FORMULA NO. ________ BATCH NO. ________

PRODUCT ________ FOR ________

TEST NO. ________ DATE ________ WT. PER GAL. ________

CONSISTENCY ________ SHADER ________

DRYING TIME ________ TESTED BY ________

BATCH	STANDARD

Typical test form.

Special finishes, particularly for industrial purposes, must be applied in the same manner in which they will be used, i.e., brushing, dipping, spraying, roller-coating, flow coating, or other methods. Batch samples and standards should be applied over surfaces and under drying conditions actually employed by the customers.

Stains, fillers, undercoats, and finishes should be applied on wood panels of the appropriate type simulating conditions in actual use.

Clear coatings and vehicles are ordinarily checked for viscosity, spe-

cific gravity, acidity and solids if desired, color, clarity, drying time, and general appearance.

After the laboratory has approved samples of finished products, the batches should be filled into containers as soon as convenient.

Samples of all batches after filling should be retained. Before filing for future reference, a final draw-down of the finished stock will determine if the batch was properly mixed and filtered at the time of filling. This precaution shows that uniform merchandise will be shipped to the customers and will indicate whether the final manufacturing operations have been properly performed.

Methods of Test. The tests which are ordinarily applied to production batches have been described by the Philadelphia Paint and Varnish Production Club.[6] This useful information is published herewith as a guide for laboratory technicians.

TEST METHODS FOR CONTROL

Purpose. To set up a standard set of methods of test for plant control and for the maintaining of laboratory determined properties.

Preferred Conditions of Test

1. Temperature 77° F or 25° C.
2. Relative humidity 50%.

Methods of Test

1. Weight per gallon. Use a clean dry cylinder of brass or any other suitable material about 110 mm high by 30 mm in diameter with the inside of the bottom rounded and the top fitted with a close-fitting cover with a small hole. The capacity with the cover on is 83.2 ml plus or minus 0.1 ml of water at 25° C plus or minus 0.5° C. This cylinder is provided with a counterpoised weight. The paint is poured into the cylinder until it is completely full and the cover placed on top, the excess paint removed from the cover and the cylinder weighed to the plus or minus 0.1 g. The weight in grams of the contents divided by 10 is the weight per gallon in pounds, and the weight per gallon in pounds multiplied by 0.12 is the specific gravity. For pastes a cylinder with volume standardized as above, about 47 mm high by 50 mm in diameter, is to be preferred. *See figures* 1 *and* 2.
2. Consistency.
   (*a*) Normal bodied paints and enamels having a consistency of 65 KU or more.
   1. Thoroughly mix the sample of paint and strain it into a 1-pt can. Place the can on the platform of the Stormer Viscometer so that the paddle-type rotor is immersed to the mark on the shaft of the rotor.
      Before starting the test, turn the rotor through approximately 100 revolutions in from 25 to 30 sec. Using different weights, determine the time required for 100 revolutions of the rotor. Select

weights that will give at least two readings within a range of 27 to 33 sec. These determinations shall be made from a running start, that is, the rotor shall be permitted to make at least 10 revolutions before the count of a test is started. A table giving values in Krebs units for shearing rates of from 27 to 33 sec per 100 revolutions is reproduced here. See, however, the note following the table. Caution: Some materials will contain considerable entrained air and should be allowed a minimum of 1 hr before running a test.

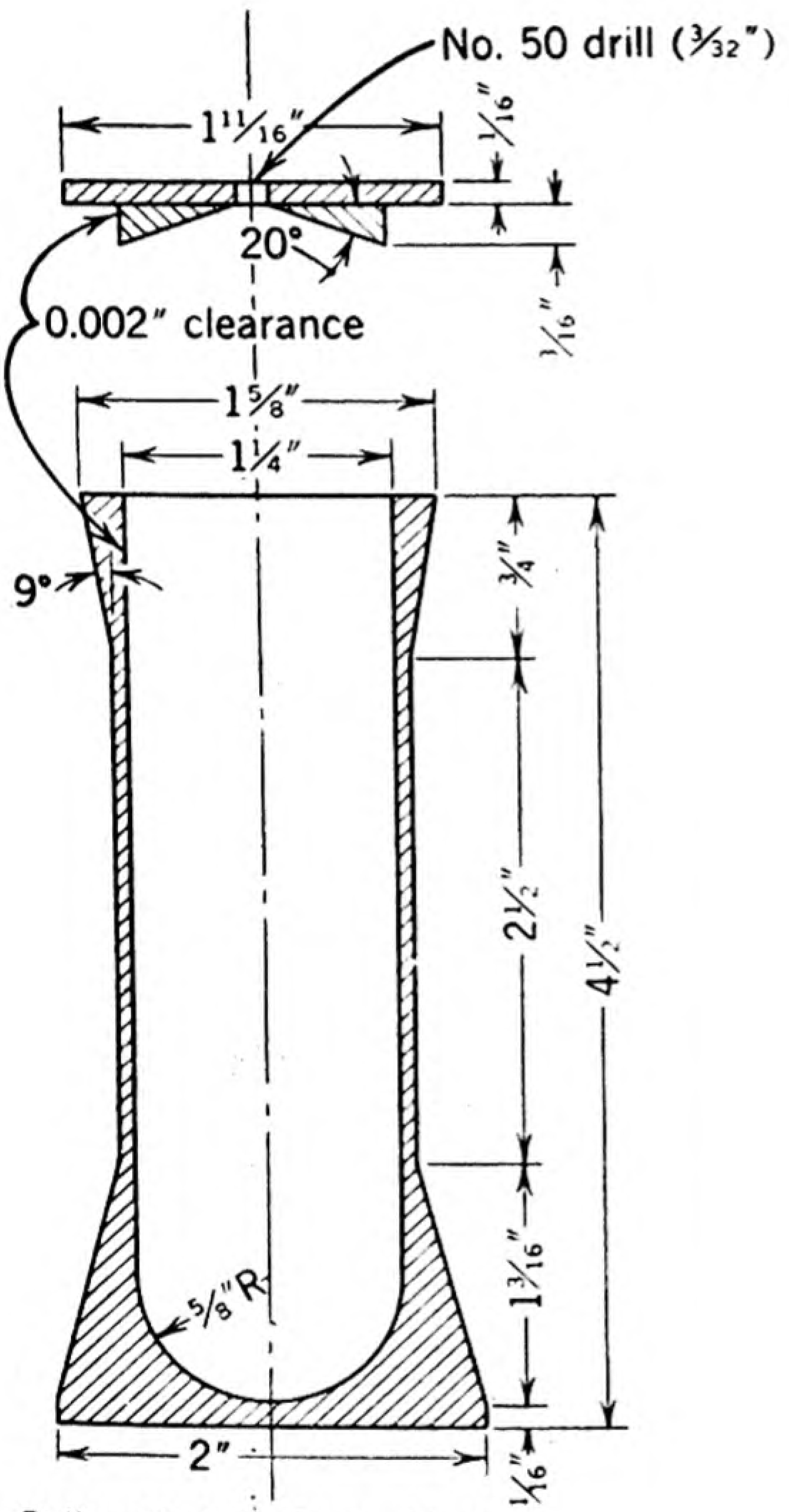
KREBS STORMER CHART WITH INTERPOLATIONS
(WEIGHT IN GRAMS)

Sec for 100 revs	75	100	125	150	175	200	225	250	275	300	325	350
27	49	57	63	69	74	79	83	86	89	92	95	97
28	51	59	65	70	75	80	84	87	90	93	96	98
29	53	60	66	71	76	81	85	88	91	94	97	99
30	54	61	67	72	77	82	86	89	92	95	98	100
31	55	62	68	73	78	82	86	90	93	95	98	100
32	56	63	69	74	79	83	87	90	93	96	99	101
33	57	64	70	75	80	84	88	91	94	96	99	101
	375	400	425	450	475	500	525	550	575	600	625	650
27	100	102	104	106	109	111	113	114	116	118	120	121
28	100	102	105	107	110	112	114	115	117	118	120	121
29	101	103	105	107	110	112	114	115	117	119	121	122
30	102	104	106	108	110	112	114	116	118	120	121	122
31	102	104	106	108	111	113	115	116	118	120	122	123
32	103	105	107	109	111	113	115	116	118	120	122	123
33	103	105	107	109	112	114	116	117	119	121	122	123
	675	700	725	750	775	800	825	850	875	900	950	1000
27	123	124	126	127	129	130	131	132	133	134	136	138
28	123	124	126	127	129	130	131	132	133	134	137	139
29	124	125	127	128	130	131	132	133	134	135	137	139
30	124	125	127	128	130	131	133	134	135	136	138	140
31	125	126	128	129	131	132	133	134	135	136	138	140
32	125	126	128	129	131	132	133	134	135	136	138	140
33	125	126	128	129	131	132	134	135	136	137	139	141

Note: On some paints a Krebs unit rating obtained at a low number of seconds per 100 revolutions will not check a rating obtained at a high number of seconds. This difference can be minimized only by using determinations made close to 30 sec per 100 revolutions; consequently, for good reproductibility only 27 to 33 sec per 100 revolutions should be used. Since using 50-g increments in the weight may fail to give a reading within the preferred section, 25-g increments may be used and a reading obtained directly from the interpolation values shown for this section of the chart.

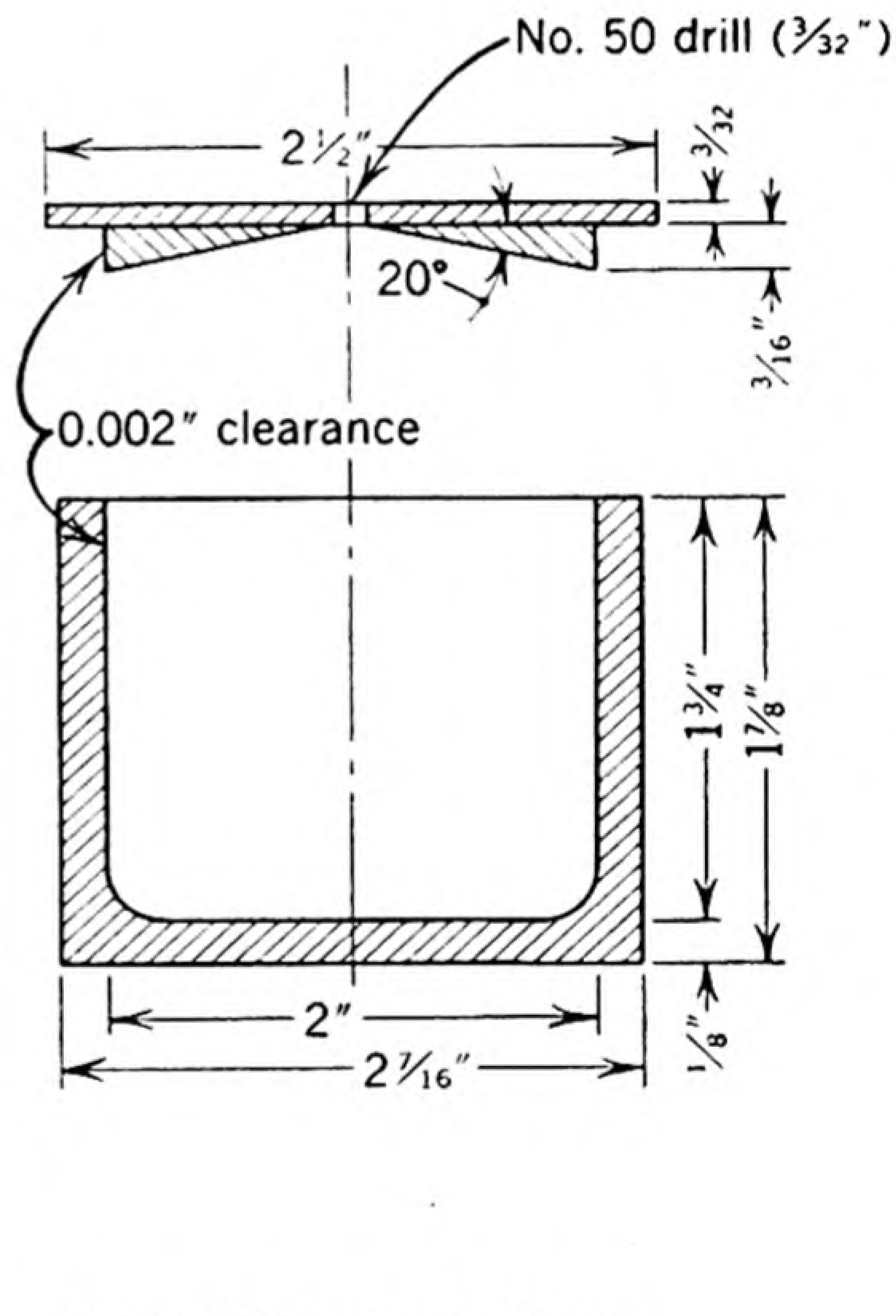
(*b*) Thin-bodied paints and enamels having a No. 4 Ford Cup consistency of 75 sec or less:

1. Use No. 4 Ford Cup with suitable support.
2. Thoroughly mix the sample of paint and strain. A minimum of solvent should be permitted to evaporate. Level the apparatus and rapidly fill with paint. Allow a moment or two for air bubbles to rise and then wipe the paint above top of the cup flush with the edges, using a piece of cardboard or a spatula. Withdraw the finger from the lower orifice of the cup and simultaneously start a stop watch. Observe the stream of coating material flowing from the orifice of the cup, and at the first distinct break in the stream stop the watch. The time in seconds is taken as the viscosity.



Gallon Weight Cup—Liquids
Not drawn to scale

Fig. 1.

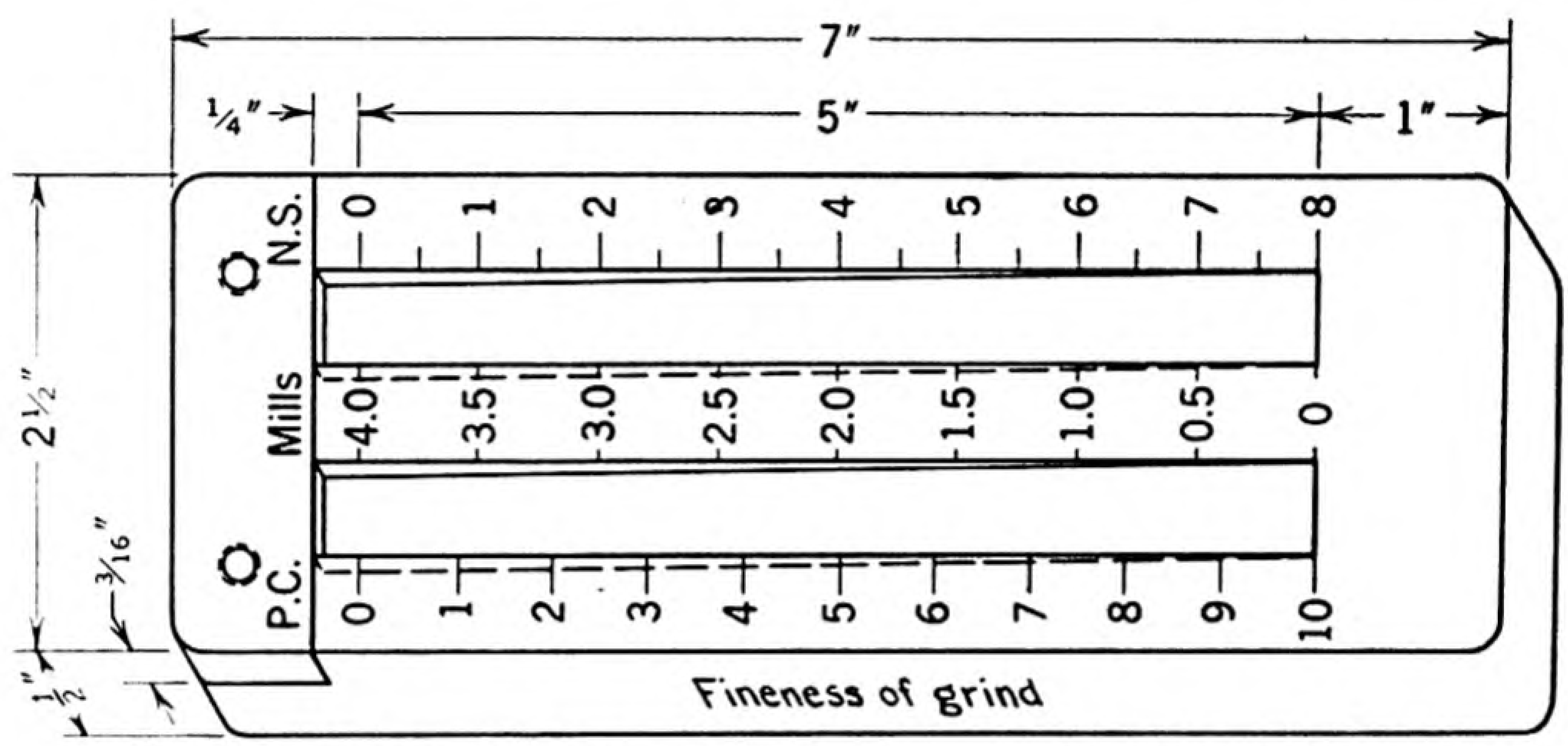


Gallon Weight Cup—Pastes
Not drawn to scale

Fig. 2.

3. Viscosity of transparent liquids.
   Determine the viscosity by comparison with secondary standard whose viscosity has been accurately determined. Gardner-Holdt tubes may be used. To determine viscosity, an empty standardizing tube is filled with material to be tested and the air space adjusted to the size in the comparison tubes. The rise of the bubble in the tube is then compared with the standard.

4. Fineness of grind (Federation Designation 10-48 has been substituted for the original recommendation).
   (a) Apparatus. The gauge (Figure 3) shall be a case-hardened steel block 7 in. in length, 2½ in. in width, and ½ in. in thickness. The top surface of the block shall be ground smooth and shall contain two parallel grooves 5¼ in. in length and ½ in. in width. The grooves shall be ½ in. apart and shall be placed approximately in the center



P.C. – Production Club N.S. – North Standard

FIG. 3. Fineness of grind gauge.

of the top of the block, leaving a ¾-in. space at the rear and a 1-in. space at the front. The grooves shall be tapered in depth lengthwise from 4 mils at the rear to zero at the front.

Within their length, they shall be graduated from 0 to 10 (Notes 1 and 2) in accordance with their depth as follows:

Distance from Zero End, inches	Depth, mils	Unit
5¼	4	Well to hold sample
5	4	0
4½	3.6	1
4	3.2	2
3½	2.8	3
3	2.4	4
2½	2	5
2	1.6	6
1½	1.2	7
1	0.8	8
½	0.4	9
0	0	10

Note 1. The gauge is also calibrated in North Standards units for operators who prefer this calibration.

Note 2. A modification of the gauge may be made by changing the maximum depth of the grooves from 4 to 2 mils and calibrating from 5 to 10 over the same length. This modification is better than the standard gauge for determining the fineness of grind of very fine dispersions.

(*b*) **Scraper.** The scraper (Figure 4) shall be a double-wedged steel plate 3½ in. in length 1½ in. in height and ¼ in. in thickness. The two wedges on the 3½-in. sides shall be rounded slightly to a radius of 0.01 in. in order to eliminate any chance of error due to wearing of a sharp edge.

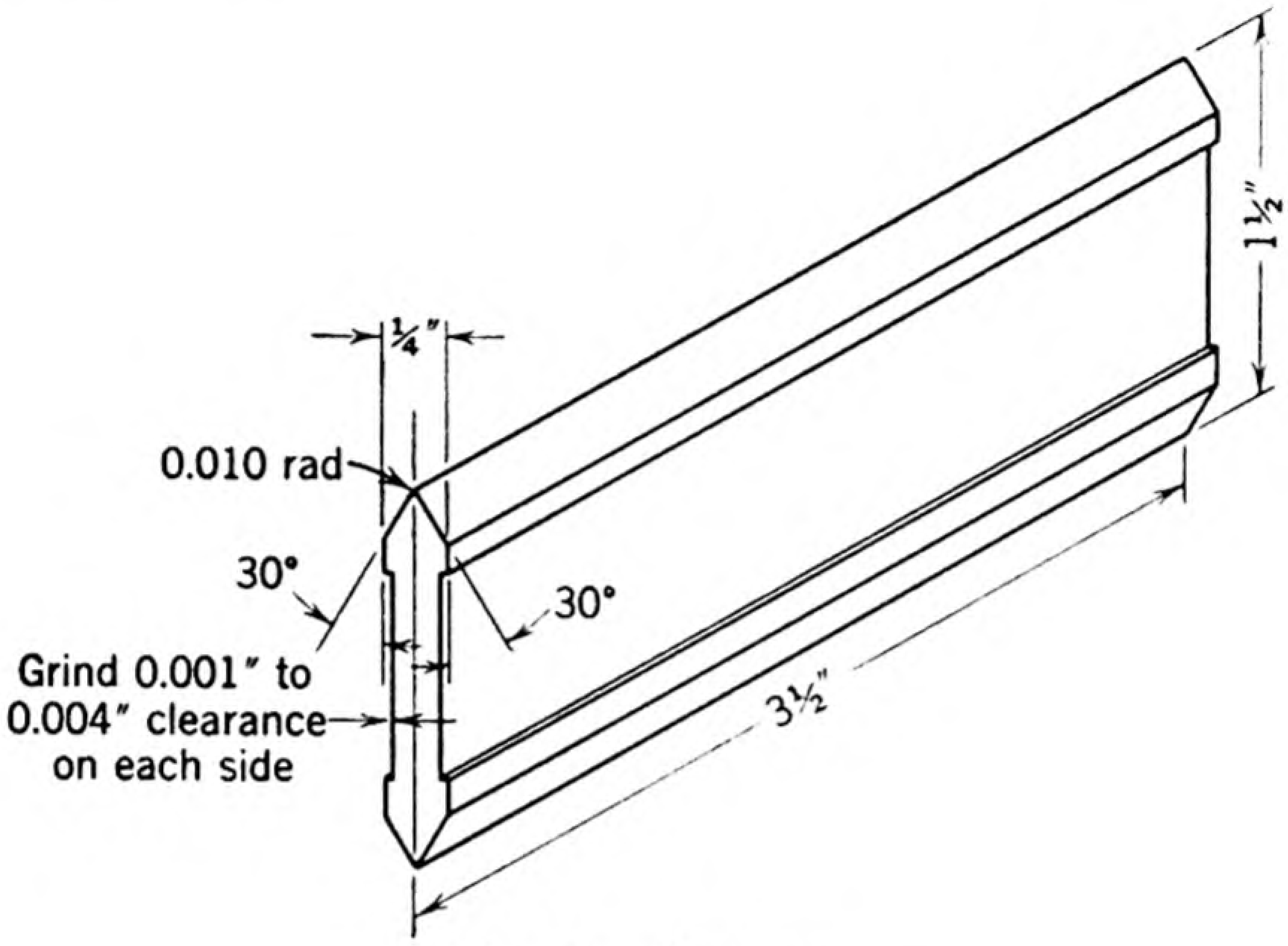


FIG. 4. Scraper.

(*c*) Procedure. 1. Strain the sample through an 80-mesh screen to remove any skins or large particles. Place the gauge on a flat, non-slippery surface with its long dimension perpendicular to and the shallow end of the grooves closest to the operator. Place in the deep end of each groove (note) a large drop of sample somewhat exceeding the amount required to fill the entire groove. Grasp the scraper between the thumb and index finger of each hand. Place the blade edgewise in close contact with the surface of the block at the extreme deep end of the grooves. Hold the scraper so that its long dimension is vertical to the surface. Draw the blade over the surface of the block, using some pressure, from the deep to the shallow end of the grooves at a uniform moderate rate. Stay almost arm's length from the block while making the draw-down, keeping the wrists and elbows fairly stiff. Maintain the blade in a vertical position during this operation and continue its motion past the near end of the grooves. This operation is intended to fill the grooves completely with the sample under test.

2. Immediately inspect the draw-down, viewing at grazing incidence, and note the point where the sample shows a predominantly speckled appearance. The specks at the end point should form almost a straight line. Disregard any scattered specks which appear in the draw-down prior to the point where the predominantly speckled appearance is noted. Note the number corresponding to the point at which this line appears and record this number as fineness of grind. A precision of one-fourth of a unit is satisfactory. Since the

reading must be made immediately, it is advisable to make a preliminary determination to establish the approximate position of the end point. A second precise reading can then be made very rapidly since the approximate position is already known.

(*d*) Report. The number on the 0 to 10 scale corresponding to the end point shall be reported as the fineness of grind of the sample. The average of two tests (four draw-downs) shall be reported as the fineness of the sample under test, expressed to the nearest one-fourth of a unit. Note: The two grooves may be used to compare directly a test sample with a known standard.

5. Hiding power.
Draw down side by side with standard on a black and white chart (Morest Form No. 010). Compare wet and after drying.

6. Color.
Draw down side by side with standard on a white opal glass.

7. Drying.
Compare drying time against standard on hiding power and color draw-downs. (*See paragraphs* 5 *and* 6).
Record set time and final dry time.

8. Gloss.
Compare gloss with that of standard, using the color draw-down (*paragraph* 6) after film is dry.

Note: Recommend 0.003 blade (Bird Applicator) 6″ wide.

9. Flexibility.

(*a*) Panels. The panels used in this test shall be cut from soft steel or tin plate, weighing not more than 25 g nor less than 19 g per square decimeter (0.51 to 0.39 pound per square foot.) The panels should be about 12 by 18 cm (4¾ in. by 7 in.) and must be thoroughly cleaned with a suitable solvent and lightly buffed with steel wool immediately before using.

(*b*) Procedure. Apply the coating in the manner and to the thickness specified. Let dry for specified period of time. Then place the panel with the coated side uppermost over a conical mandrel, held firmly by suitable supports, at a point equally distant from the top and bottom edges of the panel. Bend the panel double rapidly. The bending of the panel shall be done at the temperature specified. Examine the panel at the bend for cracking.

10. Adhesion and toughness.

(*a*) Test a flowed-out, thoroughly cleaned steel panel, air dry or baked, as required, by cutting a narrow ribbon of the film loose by means of a knife blade. The blade shall be held at an angle of about 30° to the panel. As an alternate, this test can be conducted on flexibility panels (*paragraph* 9).

11. Application properties.
Check the application for workability and appearance in the same way as the product will be used. That is, if the product will be sprayed thinned 2 to 1, thin some of the product 2 to 1 and spray it.

12. Color of transparent liquid.
Use Hellige Color Comparator with color standards numbered the same as Gardner Color Standards (1933). The tube which was used to de-

termine viscosity is slipped into the middle opening, and the wheel is revolved until a color match is obtained. The color number is read at an opening in the box.

13. Solids.

(*a*) Place a portion of the thoroughly mixed sample in a stoppered bottle. Weigh the container and sample. By means of a small spoon which will fit inside the container, transfer a small amount (3 to 4.5 g of pigmented paste or paint; 1.5 to 2.5 g if the liquid is transparent) of the material to a tared, flat-bottom dish about 8 cm in diameter (a friction top can plug). (A suitable piece of stout wire is weighed with the empty dish, is left in it, and is used as a stirrer to break up any skins during evaporation of the volatile matter.) Spread the material over the bottom of the dish.

Weigh the container, etc., again and by difference calculate the exact weight of the portion transferred to the weighed dish. Heat the dish and its contents in an oven maintained at 110° C plus or minus 2° C (230° F plus or minus 4° F) for 3 hr. At intervals any skins formed are broken up with the stirrer.

Cool and weigh. From the weight of the residue in the dish and the weight of the sample taken, calculate the percentage of volatile or non-volatile, as required.

14. Acid number.

(*a*) Reagents.

Standard alcoholic potassium hydroxide 0.1 *N* containing 6 g potassium hydroxide per 1000 ml of 95% alcohol (specially denatured alcohol formula 2B is satisfactory). This solution should be standardized against a standard acid solution, or a weighed sample of benzoic acid or other suitable standard.

Neutral solvent prepared by mixing equal volumes of toluene and alcohol (specially denatured alcohol formula 2B is satisfactory). A few drops of phenolphthalein indicator solution is added, then titrate with 0.1 normal alkali dropwise until the appearance of a faint pink color is observed. Only a few drops of alkali should be required.

Phenolphthalein indicator solution 1% in alcohol. Dissolve 1 g in 100 ml 95% (specially denatured alcohol formula 2B is satisfactory). If the sample to be titrated is yellow or brown in color, thymolphthalein (blue or purple in akaline solution) may be substituted, for the phenolphthalein.

(*b*) Procedure. Weigh accurately about a 5-g sample (3 decimal places) of the resin or varnish by difference from a stoppered vial, into a 250-ml Erlenmeyer flask. The sample size should be selected so that the volume of standard alkali used will be between 10 and 40 ml. Dissolve the sample in 50 ml neutral solvent by warming on the steam bath. After the sample has dissolved, the solution is cooled, 2 ml phenolphthalein indicator is added, and the solution is titrated with 0.1 normal potassium hydroxide (alcoholic) until the pink color remains at least a minute.

Calculation of acid number:

$$\text{Acid number of solids} = \frac{\text{Volume} \times \text{Normality} \times 56.1 \times 100}{\text{Weight sample} \times \%\ \text{Solids}}$$

In addition to the above information for plant control, the Philadelphia Club[7] has proposed standard methods and tests for the determination of specific properties of organic coatings and the measurement of film thickness, hardness, and salt-spray resistance. Other recommendations which are of general interest for laboratory operations include:

MISCELLANEOUS LABORATORY PROCEDURE

Resistance tests.

Immersion: A properly dried panel of the material shall be immersed for the required time in the specified immersion fluid contained in a glass beaker or other specified container. The panel shall be immersed to a depth corresponding to two-thirds of the height of the painted surface. It is advisable to cover the beaker with a watch glass in the case of volatile immersion fluids. The panel shall be removed at the end of the immersion period and inspected at the expiration of the various specified time intervals.

Note 1: The type of panel used must not be attacked by the immersion liquid if only film properties are being studied. In the tests to study protection against attack of the panel, the type of panel should be agreed upon by interested parties.

Exposure tests.

(*a*) Outside house paint exposure.

1. Panels. Use standard panels, preferably clapboard not less than 3 ft long. All panels should be of the same type of wood and of the same grain. For testing pigment or formulation differences, it is best to use high-grade panels of white pine. For testing the effect of this pigmentation on different types of panels, various woods should be used.
2. Panel exposure. Outside house paints should be exposed at north vertical and south vertical at one, two, or three locations, depending on needs. For different conclusions, it is best to expose in duplicate or triplicate. South 45° exposures are of questionable value.
3. Panel preparation. Panel preparation must be standardized critically. Spreading rate must be controlled, preferably by the addition of a measured volume of paint. Conditions of drying must be standardized.
4. Formulation. Sufficient controls must be necessary to tie in with standards and paints of known characteristics.
5. Exposure memorandum.
   a. Object. The reason and purpose of the exposure should be given.
   b. Formulations used should be listed in detail giving pigments used, pounds of oil, and pigments per gallon, consistency, pigment volume, and initial properties.
   c. Tinting agents. Complete information on tinting agents should be listed including source and lot number.
6. Pigments. Complete information on pigments and extenders used should be recorded and samples of each retained wherever possible.
7. Paint storage. Depending on the purpose of the exposure, sample of

each paint used should be retained for suspension properties for at least one year. Special studies may require other testing and longer retention of these sample paints.

(*b*) Interior paint and enamel exposures.

1. Panel exposure. Exposure should be made vertical in indirect light or to direct sunlight, depending on results desired. Care must be taken to be sure that the same amount of light falls on all panels. In most cases, it is necessary to rotate the panels at regular intervals. Duplicate panels are preferred whenever space and time permit.
2. Panel preparation. Panel preparation should be standardized. Panels will vary with each study and may include wood, aluminum, tin, steel, and other surfaces. Care must be exercised to have uniform panels. The same undercoater, the same backing, and the same drying or baking conditions must be used in each series. Film thickness is very important and must be controlled and measured on all panels exposed.
3. Formulation. Control formulations must be included in all exposure series. Test formulations must be recorded in detail so that work can be repeated.
4. Retain samples.
   a. Raw materials. Pigment and vehicle samples should be retained wherever possible until exposures are completed.
   b. Paints. Retained samples will vary with studies. Sufficient samples must be retained in order to make the tests under consideration. One-half pints of some products will be sufficient but usually more will be required.
5. Exposure memorandum. The exposure memorandum should contain complete details of phases of the preparation of the paints and panels, the purpose of the study, testing schedule, and tests to be made.
   Note: The size of panels for interior exposures will depend on circumstances. Panels smaller than 4 in. × 12 in. are of very questionable value. However, panels larger than 6 in. × 12 in. become very cumbersome, especially if they are to be used at more than one place.

Laboratory notebook records.

One of the important factors in a well-organized research program is the method in which the experimental data are recorded. The type of data recorded and the nature of the entry in the notebook will vary with each laboratory, depending on the type of research.

The following points on notebook procedure are general in scope. They are the minimum which are necessary for a permanent record.

(*a*) A standard-type notebook with permanent binding is recorded by number and issued only by the proper authority. This notebook, being a permanent record, is returned to the file upon completion.

(*b*) The proper date is recorded on each page, both top and bottom.

(*c*) The notebook entries are made in permanent ink and signed (not initialed) and date of signature recorded. The entry should also be signed (and dated) by a fellow chemist. The date of the next entry should follow without any blank space.

(*d*) The record should be concise and complete with no erasures. If a

correction is to be made, draw a line through the error and date the correction.

(*e*) The actual experimental data may be taken on looseleaf notes if the conditions are such that the permanent notebook might be damaged. This data must be transferred to the permanent record on the day the experiments are made.

(*f*) An index should be kept on the first or last pages of the notebook for future references. In general, the entry in the notebook should include:

1. A statement of the problem.
2. A daily record of the progress.
3. A summary and conclusions at definite intervals.
4. New ideas on any problem.

The notebook is a daily record of the work in progress, and it should be complete enough so that any chemist could check the results obtained if required to do so.

STANDARDS AND METHODS APPROVED BY THE FEDERATION OF PAINT AND VARNISH PRODUCTION CLUBS

(Designations of the American Society for Testing Materials are shown where applicable.)

Federation Designation	Name of Method	A.S.T.M. Designation
1-32	Method of Test for Tinting Strength of White Pigments	D 332-36
2-32	Method of Test for Mass Color and Tinting Strength of Color Pigments	D 387-36
3-39	Method of Evaluating Degree of Resistance to Rusting Obtained with Paint on Iron or Steel Surfaces	D 610-43
4-39	Method of Evaluating Degree of Resistance to Chalking of Exterior Paints of the Linseed-Oil Type	D 659-44
5-39	Method of Evaluating Degree of Resistance to Checking of Exterior Paints of the Linseed-Oil Type	D 660-44
6-39	Method of Evaluating Degree of Resistance to Cracking of Exterior Paints of the Linseed-Oil Type	D 661-44
7-39	Method of Evaluating Degree of Resistance to Erosion of Exterior Paints of the Linseed-Oil Type	D 662-44
8-39	Method of Evaluating Degree of Resistance to Flaking (Scaling) of Exterior Paints of the Linseed-Oil Type	D 772-47
9-39	Method of Permeability to Moisture of Organic Coatings	
10-48	Method of Test for Fineness of Dispersion of Pigmented Protective or Decorative Coatings	
11-48	Method of Test for Flash Point by Means of the Tag Closed Tester	D 56-36

STANDARDS AND METHODS APPROVED BY THE FEDERATION OF PAINT AND VARNISH PRODUCTION CLUBS (*Continued*)

Federation Designation	Name of Method	A.S.T.M. Designation
12–48	Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products	D 86-46
13–49	Method of Testing Soluble Nitrocellulose Base Solutions	D 365-39
14–49	Specifications for Black Synthetic Iron Oxide	D 769-48
15–49	Speceifications for Pumice Pigment	D 867-48
16–49	Method of Evaluating Degree of Resistance of Traffic Paint to Bleeding	D 868-48
17–49	Method of Test for Evaluating Degree of Settling of Traffic Paint	D 869-48
18–49	Methods of Sampling and Testing Turpentine	D 233-48
19–49	Methods of Testing Cellulose Acetate	D 871-48
20–49	Specifications for Titanium Dioxide Pigments	D 476-48
21–49	Specifications for Raw and Burnt Umber	D 763-48
22–49	Specifications for Raw and Burnt Sienna	D 765-48
23–49	Method of Test for Dry to No-Pick-Up Time of Traffic Paint	D 711-48
24–49	Specifications for Orange Shellac and other Lacs	D 237-48
25–49	Specifications for Raw Tung Oil	D 12-48
26–49	Specifications for Raw Soybean Oil	D 124-48
27–49	Specifications for Perilla Oil, Raw or Refined	D 125-48
28–49	Specifications for Raw Linseed Oil	D 234-48
29–49	Specifications for Boiled Linseed Oil	D 260-48
30–49	Methods of Sampling and Testing Lacquer Solvents and Diluents	D 268-49
31–49	Specifications and Tests for Soluble Nitrocellulose	D 301-48
32–49	Methods of Sampling and Testing Aluminum Powder and Paste	D 480-48
33–49	Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester	D 93-46
34–50	Method of Test for Hygroscopic Moisture (and Other Matter Volatile Under the Test Conditions) in Pigments	D 280-33
35–50	Single Record Form and the Multi-Panel Paint Inspection Sheet	D 1150
36–51	Method for Evaluating Resistance to Blistering of Paints on Metal when Subjected to Immersion or Other Exposure to Moisture or Liquids	D 714–45
37–51	Method of Test for Acetone Number of Heat-Bodied Drying Oils	D 555-49 T
38–51	Method of Test for Heat Bodying Rate of Drying Oils	D 967-48 T
39–51	Method of Test for Aniline Point and Mixed Aniline Point of Hydrocarbon Solvents	D 1012-49 T

ACKNOWLEDGMENT

A portion of the information contained in this chapter has been furnished by Mr. T. A. Thorson for the Chicago Club and is gratefully acknowledged by the editors.

REFERENCES

1. Fuller, W. R., "Paint Laboratory Organization and Administration," *Official Digest,* p. 899 (Dec., 1949).
2. Keyes, D. B., "Predictions in Product Development," *Official Digest,* p. 940 (Dec., 1948).
3. Keyes, D. B., "Training Men to Appraise and Develop Markets for Chemicals," *Chem. Eng. News,* vol. 27, no. 8, p. 488, February 21, 1949.
4. Hopkins, H. H., "Teamwork: Sales, Production and Technical," *Official Digest,* p. 894 (Dec., 1949).
5. Blackmore, P. O., "Laboratory Administration and Production Control," *Official Digest,* p. 302 (May, 1944).
6. Philadelphia Club, "Methods of Test—Part I (Plant Control)," *Official Digest,* p. 663 (Dec., 1946).
7. Philadelphia Club, "Methods of Test (Laboratory)," *Official Digest,* p. 96 (Jan., 1948).

OFFICIAL DIGEST BIBLIOGRAPHY

"Approved Standards and Methods," p. 375 (June, 1949).

Aiken, H., "Relation of the Chemical Engineer to the Industry and Standard Methods of Control of Paint and Varnish Products," p. 16 (Sept., 1944).

Baker, C. P., and J. F. Vozzella, "Evaluation of Production Club Fineness Gage and Paint Film Characteristics Based on Particle Size Distributions of Pigment Dispersions," p. 1076 (Dec., 1950).

Baltimore Club, "Study of the Factors Affecting Grinding Efficiency in Ball and Pebble Mills," p. 859 (Nov., 1948).

Baltimore Club, "Accelerated Yellowing Tests on White Enamels," p. 815 (Nov., 1950).

Birmingham Club, "Method for the Evaluation of Hard Varnish Resins and Oil Modified Resin Solutions," p. 940 (Dec., 1949).

Birmingham Club, "Specification for the Evaluation of Cellulose Lacquer Resins," p. 29 (Jan., 1948).

Blackmore, P. O., "Beyond the Blue Horizon," p. 482 (Dec., 1943).

Blom, A. V., "Film-Forming Capacity of Unsaturated Polyesters," p. 85 (Feb., 1949).

Bowles, R. F., "Further Observations of Wetting and Dispersion," p. 634 (Nov., 1947).

Bradley, T. F., "Some New Developments in Drying Oil and Varnish Technology," p. 795 (Nov., 1950).

Champetier, G., "Macromolecular Chemistry and Progress in the Paint and Varnish Industry," p. 578 (Aug., 1948).

Cleveland Club, "Weathering Machine Correlation in the Cleveland Club Area—I," p. 454 (Nov., 1945).

Cleveland Club, "Weathering Machine Correlation in the Cleveland Club Area—II," p. 518 (Nov., 1946).

Cleveland Club, "Weathering Machine Correlation in the Cleveland Club and Other Areas—I," p. 44 (Jan., 1948).

Cleveland Club, "Weathering Machine Correlation in the Cleveland Club and Other Areas—II," p. 813 (Nov., 1948).

Cook, G. S., "Protective Coatings in the Corps of Engineers," p. 541 (July, 1950).

Corbin, M., "Present and Future Trends in the Paint Industry from a Sales Viewpoint," p. 505 (Sept., 1947).

Dallas Club, "Survey of Methods Used in the South and Southwest for the Testing of Paints and Varnishes," p. 479 (Dec., 1945).

Dallas Club, "Survey of Methods Used in the Federation of Paint and Varnish Production Clubs for the Testing of Paints and Varnishes," p. 653 (Dec., 1946).

Davidson, H. S., "Electron Microscopy in Relation to Paint Pigments," p. 753 (Oct., 1950).

Dechaux, G., "At What Price Does an Expensive Paint Become a Good Bargain?" p. 1066 (Dec., 1950).

Dewey, P. H., "Rheology Factors in the Formulating and Use of Protective Coatings," p. 336 (Aug., 1946).

Doubleday, D., and A. Barkman, "Reading the Hegman Grind Gauge," p. 598 (Aug., 1950).

Dunn, E. J., Jr., "Microscopy in the Paint Industry," p. 288 (June, 1945).

Ernst, R. C., and G. R. Eudaley, "The Effect of Pigments on Oleoresinous Film Structure—III," p. 576 (Dec., 1942).

Fasig, E. W., "Relation of Colloidal Reactions to Paint and Varnish Phenomena," p. 13 (Feb., 1922).

Fasig, E. W., "Fundamentals of Colloids as Applied to Paints and Varnishes," p. 7 (Mar., 1923).

Fearnley, G., "Microscopy for the Paint Industry," p. 54 (Feb., 1936).

Flocks, K. W., "Patents and Their Importance," p. 274 (May, 1938).

Gardner, C., "Consistency and Working Characteristics of Paint," p. 61 (Jan., 1950).

Garlock, N. B., and E. W. McMullen, "Nomograph for Evaluation of Paint Exposure Panels," p. 88 (Feb., 1946).

Gehant, J. C., "Progress and Research of English Paint and Varnish Industry," p. 23 (Dec., 1929).

Glaser, M. A., "Formulation of Industrial Finishes (Metal)," p. 418 (June, 1950).

Golden Gate Club, "Color Photography as a Technical Aid in the Scientific Study of Paint Products," p. 806 (Nov., 1949).

Grundy, F. S., "Trends in Protective Coatings Technology," p. 176 (Mar., 1950).

Hall, C. H., "Relation of the Technical Man to the Industry," p. 11 (Jan., 1923).

Hallett, R. L., "Some Fundamental Paint Characteristics," p. 6 (Apr., 1923).

Harris, B. L., and I. Wolock, "Porosity of Paint Films," p. 645 (Sept., 1950).

Harris, B. L., and I. Wolock, "Surface Area-Permeability Studies of Pigmented Films," p. 750 (Oct., 1950).

Hauser, E. A., "Colloid Chemistry and the Paint and Varnish Industry," p. 16 (Jan., 1946).

Hensley, W. L., "Present and Future Trends in the Paint Industry from a Technological Viewpoint," p. 502 (Sept., 1947).

Hochberg, S., and M. P. Morse, "An Instrument for the Routine Measurement of Gloss," p. 516 (July, 1950).
Holley, C. D., "Paint Fundamentals and Their Application," p. 194 (May, 1933).
Holley, C. D., "Unfinished Paint Problems," p. 150 (May, 1934).
Hopkins, C. Y., "Modern Methods of Paint Testing," p. 94 (Feb., 1942).
Johnson, H. M., "A New Horizon for the Technical Man—Marketing Research," p. 133 (Mar., 1949).
Kappelmeier, C. P. A., "Object and Methods of Analytical Chemistry in the Field of Paint and Varnish," p. 716 (Oct., 1949).
Kienle, R. H., "The Place of Research in the Paint and Varnish Industry," p. 84 (Feb., 1935).
Kienle, R. H., "Physical Chemical Research in the Protective Coatings Industry," p. 11 (Jan., 1950).
Kortum, J. E., "The Link between the Sales and Manufacturing Departments," p. 13 (Nov., 1927).
Kropel, E., "Laboratory Control," p. 247 (May, 1938).
Lominska, C. A., "Philosophy of Paint Exposure Testing," p. 691 (Oct., 1950).
Long, J. S., "Film Formation-Film Properties-Film Deterioration," p. 150 (Apr., 1946).
Long, J. S., "Film Formation, Film Properties, Film Deterioration," p. 648 (Oct., 1949).
Long, J. S., "Observations and Some Recent Developments in Paint Practice in the U.S.A.," p. 616 (Sept., 1949).
Los Angeles Club, "Spectrophotometry of Pigments," p. 823 (Nov., 1949).
Lundberg, W. O., and J. R. Chipault, "Preparation of Several Fatty Acid Esters for Film Studies," p. 11 (Jan., 1949).
Lundberg, W. O., J. R. Chipault, and M. J. Hendrickson, "The Preparation of Alkyds and Additional Esters for Film Studies," p. 53 (Jan., 1950).
Lundberg, W. O., et al., "Progress Report of Research Program," p. 1004 (Dec., 1950).
MacGregor, J. R., "An Explanation of Compromises Necessary in Paint Formulation," p. 593 (Sept., 1931).
MacGregor, J. R., "New Concepts of Fundamental Causes of Paint Perishing," p. 77 (Feb., 1938).
Martin, S. W., "A Particle Size Distribution Approach to Paint Dispersions," p. 396 (Sept., 1942).
Matlack, R. W., "New Developments and Trends of the Paint Industry in the United States," p. 282 (Apr., 1950).
Mattiello, J. J., "Functions of Organic Coatings in Present Day Engineering Problems," p. 496 (Sept., 1947).
Mattiello, J. J., "Marburg Lecture—Abstract," p. 42 (Jan., 1947).
McMullen, E. W., and E. J. Ritchie, "New Uses for a Recording Spectrophotometer, p. 117 (Mar., 1938).
Minich, A., "Commentary on Industrial Research," p. 619 (Aug., 1948).
Moore, R. J., "Colloidal Aspects of Dispersion as Applied to Paint and Varnish," p. 83 (Feb., 1939).
Moore, R. J., "Colloids and the Paint and Varnish Industry," p. 479 (Nov., 1938).
New York Club, "Methods of Test for Evaluation of Deep Tone Flat Wall Paints," p. 873 (Nov., 1950).

O'Connor, C. J., "Our Industry's Debt to the Production Man," p. 643 (Sept., 1948).

Payne, H. F., "Application of Uniform Films," p. 400 (Sept., 1944).

Pearce, W. T., "Serviceability Testing of Paint and Varnish Products," p. 32 Dec., 1929).

Pickard, G. H., "Design of Paint," p. 366 (Feb., 1931).

Pittsburgh Club, "Correlation of the Effect of Varying Climatic Conditions on Typical House Paints and Exterior Enamels," p. 417 (Nov., 1943).

Prokop, R., "Color Standards," p. 1143 (Dec., 1950).

Rand, W. E., "Research in the Paint and Varnish Industry: Present and Future," p. 909 (Nov., 1950).

Reddy, H. A., "Texture of Dry Colors in Relation to Mill Base Production," p. 144 (Mar., 1941).

Rochow, T. G., "Resinography of Protective and Decorative Coatings," p. 400 May, 1948).

Rogers, H., "The Necessity of Research in Our Industry," p. 18 (Dec., 1929).

Rooney, J. T., "The Microscope and Its Application in the Paint and Varnish Industry," p. 65 (Feb., 1938).

Rose, C. H., "Fifty-Seven Research Problems," p. 1 (Jan., 1944).

Schmutz, F. C., "Service Testing in the Laboratory," p. 300 (Dec., 1930).

Scofield, F., "Scientific Instruments in the Paint Industry," p. 130 (Mar., 1946).

Sieplein, O. J., "Paint Proving in South Florida," p. 309 (Apr., 1950).

Sterne, E. T., "Has the Technical Man a Place in Business Administration?" p. 658 (Nov., 1931).

Stine, C. M., "Benefits of Research to the Production Man," p. 22 (Dec., 1927).

Tabern, G. W., "Maintenance of Standards," p. 21 (Mar., 1927).

Vesce, V. C., "Visual and Infrared Photographic and Spectrophotometric Study of Pigments and Pigmented Coatings," p. 217 (June, 1943).

Vogel, M. J., "The Practical Application of Luminescence," p. 905 (Nov., 1950).

Weed, F. G., and N. P. Beckwith, "Industrial Finishes and Finishing," p. 383 (May, 1948).

Werthan, S., "Paint Evaluation," p. 89 (Mar., 1933).

Werthan, S., "Some Formulation Fundamentals of Trade Sales Finishes," p. 182 (Mar., 1950).

Wescott, G. H., "Materials and Equipment Problems," p. 254 (May, 1945).

Wiggam, D. R., "Some Trends in Protective Coatings," p. 536 (Oct., 1947).

ADDITIONAL FEDERATION OF PAINT AND VARNISH PRODUCTION CLUB PAPERS

C.D.I.C. Club, "Putting the Varnish Laboratory Batch into Production," *NPVLA Sci. Sec. Cir.,* p. 359 (Nov., 1934).

C.D.I.C. Club, "A Study of Fluorescence Analysis and Its Application to Paint Raw Materials," *NPVLA Sci. Sec. Cir.,* p. 279 (Nov., 1937).

C.D.I.C. Club, "Fluorescence Analysis—II," *NPVLA Sci. Sec. Cir.,* p. 337 (Nov., 1938).

Chicago Club, "Study of the Measurement of the Consistency of Coating Materials," *NPVLA Sci. Sec. Cir.,* p. 365 (Nov., 1936).

Detroit Club, "Phenomena in Paints and Varnishes," *NPVLA Sci. Sec. Cir.,* p. 247 (Nov., 1937).

Detroit Club, "Maintenance of Samples of Standards, Shipments of Batches of Varnish, Paint, and Lacquer," *NPVLA Sci. Sec. Cir.*, p. 626 (Nov., 1927).

Ernst, R. C., and F. R. McQuilkin, "A Study of Oleoresinous Film Structure—I," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 213, 1940.

Ernst, R. C., and W. H. Lubbers, "A Study of Oleoresinous Film Structure—II," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 131, 1941.

Keyes, D. B., "Value of Research to Industry," *NPVLA Sci. Sec. Cir.*, p. 663 (Dec., 1931).

Louisvivlle Club, "Use of the Microscope in the Paint Laboratory with Notes on Ultraviolet Light," *NPVLA Sci. Sec. Cir.*, p. 209 (Nov., 1938).

Murray, C. A., and F. E. Bartell, "Wetting of Pigments by Linseed Oil and Paint Vehicles," *NPVLA Sci. Sec. Cir.*, p. 151 (Oct., 1939).

New England Club, "Decorative Finishes: Materials and Methods Used in Their Creation," *NPVLA Sci. Sec. Cir.* (Nov., 1932).

New York Club, "Color Control in the Paint Plant," *NPVLA Sci. Sec. Cir.*, p. 419 (Oct., 1930).

New York Club, "Survey of Certain Research Problems in Paint and Varnish," *NPVLA Sci. Sec. Cir.*, p. 37 (Nov., 1938).

New York Club, "Methods for Producing Uniform Films," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 145, 1940.

Philadelphia Club, "The Technician in the Paint and Varnish Industry," *NPVLA Sci. Sec. Cir.*, p. 521 (Nov., 1933).

Philadelphia Club, "Proposed Pictorial Standards for Designating Degrees of Failure of Organic Films—I," *NPVLA Sci. Sec. Cir.*, p. 79 (Oct., 1939).

Pittsburgh Club, "Standardization and Matching of Opaque Paint Colors," *NPVLA Sci. Sec. Cir.*, p. 383 (Nov., 1936).

Pittsburgh Club, "Correlation of the Effect of Varying Climatic Conditions on Typical House Paints and Exterior Enamels," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 123, 1941.

Toronto Club, "Relationship between Laboratory and Factory Batches," *NPVLA Sci. Sec. Cir.*, p. 643 (Dec., 1931).

Western New York Club, "Raw Material Testing in a One Man Paint Laboratory," *NPVLA Sci. Sec. Cir.*, p. 291 (Nov., 1937).

Western New York Club, "A System of Minimum Test Requirements for Control in the Paint, Varnish and Lacquer Industry," *NPVLA Sci. Sec. Cir.*, p. 327, (Nov., 1936).

CHAPTER 10

FIRE PROTECTION, SAFETY AND HEALTH

FIRE PROTECTION

The study of the problem of fire protection and prevention should start with plant location and public services that will or will not be available. The lack of any one or more of the following factors should be remedied by the management.

Factors to be considered for plant location:

1. Public water supply.
2. Public fire department.
3. Local structural conditions.
4. Public fire alarm system.
5. Neighboring hazards or occupancies.
6. State and local laws.
7. Local police protection.

These factors should be discussed with the insurance division of the inspection department having jurisdiction:

Exposure fires account for a substantial part of fire losses and the severity of exposure is controlled by one or more of the following:

1. Open space between buildings.
2. Fire walls without openings.
3. Fire department hose streams.
4. Fire-resistive walls with protected openings.
5. Outside sprinklers.
6. Inside sprinklers.
7. Exposure of storage tanks of inflammable material above ground.

Fire department protection is the determining factor in controlling exposure fires.

Open space between building units, parapet walls on roofs, and fire walls without openings where practicable are the best protection against exposure fires. Buried tanks are best when possible.

Fire Causes in Paint and Varnish Plants. Varnish and oil cooking cause over one-fourth of the fires in paint and varnish plants; poor

building construction, deposits in vent stacks, overheating of kettles, and boiling over are responsible for many fires.

Processing equipment that is defective or not properly installed with adequate clearance from combustible materials is also a contributing factor.

Other causes are explosions of vapors from tanks and kettles, spillage of inflammable liquids, poor ventilation, spontaneous ignition of oily cloths, rubbish, sweepings, and chemicals.

Segregation of Plant Units. It is desirable that raw-material storage, manufacturing, and finished stock storage be segregated, if possible. Raw materials can be housed in less expensive buildings; with units separated, control of a fire is easier and total insurance charges will be less than when warehousing is combined with manufacturing.

When a more severe fire risk is involved, such as in the manufacture of lacquers, concentration of processes should be avoided by having smaller units detached in separate buildings of one story with fire walls as needed. There should be internal partitions of at least 2-hr resistance, based on standard fire-test specifications.

Tank storage areas (above ground) should be separated from manufacturing areas at a distance of not less than 100 ft and enclosed within dikes of earth or concrete that will hold one and a half times the volume of the total tank capacity.

Water Supply. Private independent water supply is considered best.

The reliability of any public water system can be determined by engineering estimates. The source must be sufficient to furnish all the water that combined fire and domestic needs may call for at any one time.

A great many water systems are becoming inadequate, owing to large shifts of populations into manufacturing communities and to the fact that outlying districts come into the orbit of the older city with no new pumping stations, water reserves, or water mains being added. Old water mains are becoming overburdened. Another factor of importance is alleged lowering of the water table, thereby affecting wells. This has been disproved in some localities, but a regular check of water supply should be made as conditions change.

The following chart is taken from the Crosby-Fiske-Forester *Handbook of Fire Protection* to show the estimated water requirements for protection according to population.

For cities of over 200,000 population, 12,000 gal per minute are needed with an additional 2000 to 8000 gal for a second fire.

These values are good figures to take as a starting point. Where especially hazardous occupancies are involved, an increase in demand can be expected.

Population	Average Gallons per Minute Needed for Mercantile District of Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Building and Equipment Precautions

The manufacture of paint, varnish, and lacquer products presents unavoidable fire hazards. Buildings should be designed or revamped to minimize and check fires. All inflammable materials should be protected from exposure, first by being placed away from flame sources. Metal parts such as buildings, machinery, and pipe lines should be grounded.

The proper venting of storage tanks is important. Drains, scuppers, and vents should be installed to drain off water and heavy vapors.

Because of the hazards involved, more exits for personnel in manufacturing areas of paint, varnish, and lacquer plants should be installed than normal for other industries.

Reasonable travel distances to available exits under varying circumstances are:

High fire hazard—not more than 75 ft.
Average fire hazard—not more than 100 ft.
Sprinklered buildings—not more than 150 ft.

Where large amounts of inflammable materials are used and the building is sprinkler equipped, the rule of not more than 75 ft should be observed.

At least two exits, remote from each other, are necessary, with additional exits according to the number of persons and the relative fire danger.

Fire Doors. Fire doors vary as to type and kind, depending on the

purpose, size, and location of the openings involved. The openings also govern the type of mounting, frames, and accessory hardware.

NATIONAL BOARD OF FIRE UNDERWRITERS CLASSIFICATION

Class A. Openings subject to severe fire exposure for considerable length of time, as in lacquer plants. It is sometimes necessary to have two automatic sliding-type doors, one on each side of the wall, known as double doors.

Class B. Vertical shafts subject to severe exposures such as stairs, elevators, etc. These require a very efficient single door.

Class C. Corridor and room partitions. These may have wired glass in an area under 1296 sq in.

Class D. Openings in exterior walls with severe fire exposure. Classes A-B-C-D must be able to withstand fire for a fairly long time.

Class E. Openings in exterior walls with moderate fire exposure.

For more facts, the reader is referred to *Pamphlet* No. 80 of the National Board of Fire Underwriters.

Doors used for exits except sliding doors should swing with exit travel. Doorways protected by fire curtains are not counted as exits. They should be avoided as such by having approved doors accessible and equipped with panic hardware.

Floors. The types and kinds of floors are governed by many factors. For lacquer plants, non-sparking and conductive flooring is suggested to drain to earth the body static and static from vehicles generating charges that may tend to build up on containers, hand trucks, and other equipment.

Floors should be waterproofed to minimize water damage under concrete. Special precautions should be taken where especially hazardous processes are involved which may require large quantities of water for fire extinguishment. Scuppers and floor drains should be installed. Wooden floors should be double to avoid the payment of additional insurance that most rating schedules charge for single floors.

For floor openings where pipes and other conditions require openings, precautions should be taken to place curbs around the openings at least 1 or 2 in. high and a closing top to prevent heat or fire from spreading to other floors.

Windows. Windows shoud be wired glass with hollow metal frames. This is very important when exposure is to adjacent buildings. Windows should be self-closing type with fusible links or chains. Outside shutters are suggested where a severe fire hazard from unprotected exposure exists.

Propping windows open should be discouraged.

Windows should be promptly repaired when broken or screened to avoid admitting sparks.

Windows should open out where explosions are a possibility. The

window panes of lacquer plants should be scored for easy breakage in case of explosion, or at least in those areas where explosions are possible.

Electrical Equipment. Many approved types of equipment on the market are used successfully in the paint and varnish industry and are classified as follows: Class I, Group D, as defined by Article 500 of the National Electrical Code. This electrical equipment is to be used where inflammable materials are handled and where explosive vapors exist. Explosionproof lights and circuit-breaker light switches are indicated. Receptacles of all kinds, motors, starters, and portable devices should be of approved explosionproof type. Proper installation is required by sealing off condulets. *Portable electrical equipment must be reduced to the minimum in lacquer plants.*

It is important that exceptionally good care be taken of electrical equipment in paint, varnish, and lacquer plants where hazardous materials are handled because breakdowns of explosionproof installations are possible and disaster can follow.

Care must be taken when lights are being replaced and repairs are being made that circuits are shut off so that sparks do not occur.

Careful layout of electrical equipment makes it possible to reduce the amount of special devices needed in hazardous locations by the installing of switches and motors in less hazardous areas.

(The Underwriters Laboratories, Inc., have a published list of inspected and approved electrical equipment which may be secured by writing to 207 Ohio St., Chicago 11, Ill.)

Tanks. The storage of inflammable liquids in tanks that are tight and substantial either above ground, underground, or beneath buildings is an accepted practice. The greatest hazard comes from filling, venting, and emptying these tanks if proper safeguards are not taken.

Underground tanks with a rust-resisting protective coating applied are regarded as the best. Tanks should be covered with at least 2 ft of earth or concrete. Cinder fills should be discouraged because of the corrosive action on metal.

Some means must be provided to permit air or vapor to escape or enter while tanks are being filled or emptied. This prevents tanks from rupturing or collapsing. These vapors are inflammable and should be dissipated in a safe location away from any flame sources.

Flame arrestors are required on vent pipes. These are made in several types.

For adequate fire protection and economy, the selection of the tank vent is dependent on the type of tank used. Inflammable liquids with a flash point of 110°F or less should have a vent with flash arrestor and a combined pressure-vacuum relief valve which requires inspection at regular intervals.

The sizes shown in the following table are for free circular openings and are based on an orifice coefficient of 0.7 and a vapor density of 2.5, taken from the National Fire Protection Association's bulletin, Suggested Flammable Liquid Ordinance.

Capacity of Tank in Gallons	Minimum Size of Vent in Inches With 1 lb per sq in. Working Pressure	With 5 lb per sq in. Working Pressure
Up to 1,000	2½	1½
4,000	3¾	2½
18,000	5½	3¾
25,000	6	4
56,000	7¼	5
100,000	8¾	6

Lacquer-Plant Precautions

Vessels used in the manufacture of lacquer should be all-metal with tight fitting tops of non-sparking materials clamped on to prevent loss of vapor. These tanks should be grounded to a permanent ground by copper wire not smaller than No. 6 and larger if possible.

The resistance to ground should not be greater than 5 ohms. Chain grounds are not advisable. Two-wire, rubber-covered No. 16 wire with battery clamps is recommended.

Carbon dioxide nozzles should be placed at openings to be operated manually or automatically for fire protection.

Portable tanks should be covered and grounded when in use.

Wheels on portable tanks should be of non-sparking metal. Floor plates should be attached to grounding circuit to take off charges of static from portable equipment.

Platform scales for weighing solvents should be covered with a non-sparking metal and grounded.

All hand tools used in process operating should be of the non-sparking type. Filling pipes or nozzles should be of non-ferrous metal and grounded by No. 2 rubber-covered superservice No. 16 wire between nozzle and the vessel being filled.

Skids used in unloading of nitrated cotton should be of wood with the metal parts of non-sparking-type metal. Bolts should be countersunk to prevent possible struck sparks.

Fire-Extinguishing Equipment

The selection of fire-extinguishing equipment depends wholly on the nature of the risk involved. The apparatus selected must be suitable and adequate for the hazard when encountered.

Maintenance is of vital importance and should be carefully followed

through to assure that the equipment will operate efficiently when needed.

Although there is potential danger in locations where volatile liquids, raw materials, and finished products are stored, the greatest hazards are at points where the materials are being processed. With proper fire-extinguishing equipment at hand and personnel trained to use it, fires can be controlled or put out when they start. If the hazard is too great, automatic equipment properly designed to meet the emergency should be installed.

FIRE EXTINGUISHERS AS CLASSIFIED BY THE UNDERWRITERS' LABORATORIES

Type	Size	Classification
Chemical solution	2½ gal	A-1
(soda and acid)	1¼–1½ gal	A-2
Water	2½ gal (stored pressure cartridge)	A-1
	5-gal pump	A-1
	50-gal cask with 3 pails	A-1
	25- 35-, and 40-gal bucket tanks (6 pails)	A-1
	2½-gal pump	A-1
	12-qt pail	A-5
Anti-freeze solution	2½ gal (stored pressure cartridge)	A-1
	5-gal pump	A-1
	50-gal cask with 3 pails	A-1
	25-, 35-, and 40-gal bucket tanks (6 pails)	A-1
	2½-gal pump	A-1
	12-qt pail	A-5
Foam	2½ and 5 gal	A-1, B-1
	1¼–1½ gal	A-2, B-2
Loaded stream	1¾ and 2½ gal	A-1, B-2
Vaporizing liquid	1 gal, 2 gal, and 3 gal	B-2, C-1
(carbon tetrachloride)	1 qt, 1¼ qt, and 2 qt	B-2, C-2
Carbon dioxide	15 lb and 20 lb of CO_2	B-1, C-1
	7½ lb and 10 lb of CO_2 (with 24″ cone)	B-1, C-1
	4 lb of CO_2	B-2, C-2
	2 lb of CO_2	B-4
Dry compound	15 lb and 25 lb dry chemical	B-1, C-1

A-1. Extinguisher is suitable for use on paper or wood, and one extinguisher makes a unit.

B-2, C-3, etc. Extinguisher is suitable for use on inflammable liquids and requires two or three appliances to make a unit.

C-1 or C-2. Extinguisher is suitable for use on electrical equipment and requires one or two appliances as indicated.

There are three general classes of fires:

Class A—Incipient fires in ordinary combustibles such as wood, paper, coal, and rubbish, on which the quenching and cooling effect of water is of importance.

Class B—Incipient fires in small quantities of liquids, such as gasoline, naphtha, oils, and greases, on which the blanketing or smothering effect of the extinguishing agent is of first importance.

Class C—Incipient fires in electrical equipment where the material used in extinguishers must be a non-conductor of electricity.

The Underwriters' Laboratories make further distinction for extinguishers, assigning them numbers from 1 to 5. This represents the quantity of extinguishers of a given size needed to extinguish a unit-size fire.

Certain established standards for hand extinguishers govern their use and the number that will be needed. The inspection department having jurisdiction should determine the number.

A guide to number and kind as recommended by the National Fire Protection Association includes:

Class I. Light-hazard occupancies. Because of the relatively small amounts of combustibles, units will be so located that an employee will not travel more than 100 ft to reach the nearest unit; at least one unit for 5000 sq ft of floor area.

Class II. Moderate-hazard occupancies. In ordinary occupancies, such as stores, warehouses, and some manufacturing, an employee should not have to travel more than 50 ft; each unit for every 2500 sq ft of floor area.

Class III. Extra-hazardous occupancies. Including paint, varnish, and lacquer manufacturing, where incipient fires may be expected, units should be located so that not more than 50 ft must be traveled to acquire extinguishers; additional extinguishers should be placed closer as severity may indicate.

Fire-Protection Systems. Effective systems of protection involve many factors. Insurance companies and manufacturers of fire equipment usually provide an engineering service and will help with specific recommendations and in checking blueprints and plans. Fire prevention bureaus of the local fire department will interpret codes and the required standards.

Water Sprinklers. The automatic sprinkler systems are the most reliable means of fire protection. The National Fire Protection Association report shows that sprinklers are 95 per cent effective in paint and varnish works:

65.4%	Fire extinguished.
30.1%	Held in check.
95.5%	Satisfactory.
4.5%	Unsatisfactory.

The most common sprinkler system is the *wet system.* The piping system is completely filled with water under pressure which is immediately discharged when a sprinkler head opens.

The *dry pipe system* is used largely in unheated buildings. They are said to be somewhat less effective than the *wet system,* owing to delay caused by air discharge before water can flow. A dry system in areas where dust-laden conditions exist may temporarily accelerate burning.

To be effective, all areas, with few exceptions, should be protected. There should be extensions under decks, platforms, and enclosures. Stock should never be piled around sprinklers so as to obstruct the water. The pressure and water supply must be adequate.

Special instructions on the placing of sprinklers in show windows, boxed machines, metal air ducts, ventilators, and enclosed spaces under racks, platforms, and over electrical generators, transformer apparatus, and switch boards are important.

There are special sprinkler heads available with approved coating for protection against corrosion, or sprinklers designed to possess high resistance to corrosion. Where heads are exposed to corrosive conditions, they may be wax coated; care in handling should be observed.

RATINGS OF SPRINKLER HEADS*

Maximum Room Temperature at Ceiling	Rating Designation	Operating Temperature Non-Solder Type	Operating Temperature Solder Type	Color
100°F	Ordinary	135°–150°F	155°–165°F	Plain bronze
150°F	Intermediate	175°F	212°F	White
225°F	Hard	250°F	286°F	Blue
300°F	Extra hard	325°F	360°F	Red
375°F	Extra hard	400°F		Green

* From Crosby-Fiske-Forester *Handbook of Fire Prevention.*

Over very severe hazards, as in lacquer plants, sprinkler heads must be closer together, but there should never be more than 100 heads to a valve.

When possible, sprinkler heads that produce a fine spray are advisable over inflammable liquids.

In many situations water from regular automatic sprinklers will control fires fed by inflammable liquids. The effectiveness depends on the flash point, room temperatures, and quantity of material involved. If materials have flash points of less than 200°F, special protection is needed, such as automatic closing covers and special extinguisher systems of CO_2 gas or foam. For lacquers and alcohols, a special foam is needed, since regular-type foam breaks down in the presence of alcohols.

Special automatic extinguishing systems may be classified under the

following headings: (*a*) automatic water-deluge system; (*b*) automatic water-spray system; (*c*) automatic foam system (three kinds of foam are available); (*d*) automatic carbon dioxide system.

Automatic Water-Deluge System. Automatic water-deluge systems are used where ordinary sprinkler systems cannot give proper protection to personnel or processes that are exposed to flash fires and where copious amounts of water are needed. They consist of open sprinkler heads, oversized piping, and heat-rise actuators to transmit signals to release or to actuate valves.

Automatic Water-Spray System. Standards governing regular sprinkler systems should be followed except that piping must be galvanized or made of material not readily corrodible. These systems are used successfully over transformers and outside storage tanks of inflammable materials. Water spray is used as a supplementary protection with regular sprinkler systems.

Effective protection is dependent on having adequate pressures and quantities of water available at the heads (sometimes special spray heads are necessary). Each system requires individual consideration as to the size of piping and location of nozzles. These systems involve the use of a dry pipe system operated by heat-rise and water-flow actuators. They must be especially designed for the hazard to be protected.

Automatic Foam System. The blanketing or smothering effect of foam makes this form of protection very efficient where inflammable liquids are involved. Any tank of inflammable liquid over 20 ft in diameter should be equipped with a fixed foam extinguishing system. The mixing chamber for the fixed system should be at least 75 ft from the tank.

A sufficient amount of foam powder or liquid should be stored near the mixing tank. The foam substance should be selected carefully in relation to existing conditions. The kinds commonly used are:

1. Insoluble in hydrocarbons.
2. Insoluble in alcohols. Effective for lacquers or where alcohols are present. (Can be used on hydrocarbons but is more expensive than Number 1.)
3. Mechanical foam. Intended for hydrocarbons.

Some factors which must be considered with respect to foam protection include:

Type of system (inflammable materials govern type of foam).
Type, size, and location of discharge outlets.
Size and length of pipes.

Pressures.
Rate of foam delivery.

When large quantities of foam are desirable, foam generators are employed as described below.

1. Portable generators consist of a special play pipe to be attached to a cotton-rubber-lined hose either $1\frac{1}{4}$ or $1\frac{1}{2}$ in. and a pick-up tube that is placed in a container of foam liquid.
2. There are two styles of hopper-type generators, one of which has a single foam-producing dry chemical.
   (a) Regular size uses 50 lb of powder per minute for 100 psi water pressure (inlet pressure) and produces 500 gal foam.
   (b) Large size uses 190 lb of powder per minute for 100 psi water pressure and produces 1300 gal foam.

The rate of application is determined by the equipment used. A rate of $\frac{3}{4}$ gal foam for each square foot of liquid area per minute usually is adequate, if the foam is flowed on gently.

If foam streams are used, the rate of application will increase to 1, $1\frac{1}{4}$, or $1\frac{1}{2}$ gpm foam per square foot.

Ordinary chemical foam is not suitable for the protection of tanks of alcohol, acetone, carbon disulphide, and similar water-miscible inflammable liquids.

It is common practice to specify sufficient foam to extinguish a fire in the largest single area to be protected.

Foam in liquid form requires protection from freezing.

Foam systems involve many special problems, and it is recommended that only those who are experienced be employed for installation and that the inspection bureau having jurisdiction be consulted.

Automatic Carbon Dioxide System. These systems are primarily effective because they reduce the oxygen present so that combustion can no longer be supported. One lb of carbon dioxide in liquid state when released will produce about 8 cu ft of free gas.

The methods of storage of the gas are referred to as high-pressure or low-pressure systems.

High-pressure systems. The carbon dioxide is stored in steel cylinders; these cylinders contain 50 lb or more of liquid carbon dioxide gas at the points where needed. The pressure at 70°F is about 849 psi.

Low-pressure systems. The carbon dioxide gas is stored in an insulated tank where mechanical refrigeration keeps the temperature at 0°F. The pressure at this temperature is approximately 300 psi.

These systems involve special engineering problems, and only approved equipment can be used. (Detailed requirements are given in the

National Fire Protection Association Standards for Carbon Dioxide Fire Extinguishing Systems and also *NBFU Pamphlet* No. 12.)

Water-Spray Protection. Water spray, or fog was developed for fires that water in its conventional form could not control. It also was developed for application where extinguishment with the minimum amount of water was necessary.

The application of water spray has limited effectiveness on Class A fires, being effective only on the surface. It is effective on Class B fires (liquids) where the flash point and viscosity are high, although it is less successful on lighter or more volatile liquids.

Water spray can be used on electrical equipment because the spray does not have the electrical conductivity of a solid stream of water.

Portable Fog or Water-Spray Equipment. The supply of water for fog equipment can be made available by independent risers with or without booster pumps and fog nozzles on hose lines or the fog equipment may operate off sprinkler systems and increased pressure may be secured through outside city fire department connections or installed pressure pumps.

On properties equipped with automatic sprinklers, the insurance department or the inspection department having jurisdiction should be consulted to determine if the nozzle system (permanently piped system) or supplementary hand hose lines can be used in connection with the sprinkler system.

Many types of portable fog nozzles will extinguish fires successfully. Of these there are two general types, *low-velocity* and *high-velocity* nozzles.

The low-velocity nozzle is distinguished from the high-velocity spray by the difference in the transmitted velocity of projection; velocity controls the size of the droplets of water and the distances covered.

The nozzle size and type in turn are governed by the size of hose, pressures, and patterns to be used. Furthermore, each type of approved spray nozzle is specially adapted for certain uses and is not always suitable for other purposes.

The characteristics of spray nozzzles vary among manufacturers. The standard recommendation of the National Fire Protection Association is that the engineering departments of the manufacturers be consulted because they are familiar with the scope and limitations of their own equipment.

A low-velocity nozzle is generally used on low-flash-point materials where agitation of the surface of the burning material must be avoided. Owing to the short projection of the low-velocity fog pattern, play pipes or applicators (3 ft to 12 ft in length) are generally used. The fog must

be applied directly over the entire burning area to be most effective. Also the areas must be accessible because the projection of low-velocity fog is only a short distance. The high-velocity portable nozzle is useful in large areas and has several advantages. Because of its better projection range, it affords excellent protection to the operator and is applicable to the heavier materials such as oils, paints, etc. Under proper conditions it is effective on some of the lighter inflammable liquids.

It should be remembered that, due to the limited range of all spray nozzles as compared with straight streams, there are limits to the size of fires that may be controlled, especially where large amounts of inflammable liquids are involved.

Alarm Systems and Equipment. Many types of automatic and manual systems have been devised to cover a wide range of situations, such as those for large and small cities or towns and large and small industrial plants.

Fire-alarm systems fall into four general automatic or manual categories:

1. Local systems which detect and notify occupants of a fire but do not transmit alarm signals to fire departments or central control stations.
2. Central services which own and maintain service for private properties and transmit the call to local fire and police departments and notify proper officials of the properties..

SUGGESTED COLOR SAFETY CODE

Color	Symbol	General Use	Pipe Identification
Red	Square	Extinguishers, alarm boxes, and other fire equipment	Sprinklers or other fire extinguishing systems
Yellow or yellow & black	Band or stripes	To call attention to hazards where tripping, stumbling, and the like exist	Pipes containing hazardous material
Orange	Triangle or arrow	Electrical hazards—parts of machinery that are dangerous	Same as yellow
Green	Cross	Safety equipment—first aid and medical kits	Safe and non-valuable materials such as water or air
Blue	Circle	Caution warning—equipment not to be started or moved	For protective materials other than fire
White or aluminum	Star	Sanitation—traffic lanes, aisles, corners, and other uses	Same as green

3. Proprietary systems which are owned and maintained by the property owners who initiate measures for extinguishing a blaze from their own control stations.

4. Auxiliary systems which connect local detection and alarm systems with a municipal fire alarm box.

Watchmen supervisory systems may be separate or used in connection with fire-signal systems.

Hazards

Spontaneous Ignition. This may be defined as the oxidation of a substance with such rapidity as to create heat in sufficient amount to ignite it. It is impossible to predict when spontaneous heating will occur, for under favorable conditions, where ventilation is restricted, ignition may be a matter of hours, days, or months.

Materials which may induce combustion under certain circumstances are grouped as follows:

Group I. Substances not themselves combustible, but may cause ignition, i.e., calcium oxide in contact with water produces heat.

Group II. Substances that develop ignition points below ordinary temperatures, i.e., turpentine in the presence of chlorine.

Included in this group are substances which undergo chemical change with other compounds to form products that are capable of oxidation at ordinary temperatures.

Group III. Combustible substances which may undergo sufficient oxidation at ordinary temperatures to reach the ignition point, such as the drying oils, i.e. dehydrated castor oil, linseed oil, menhaden oil, oiticica oil, perilla oil, soybean oil and tung oil.

Inflammable Liquids. A knowledge of the flash points of solvents, oils and other inflammable liquids will serve to make the personnel handling them more cautious and less apt to take unnecessary chances.

Pigment Hazards. In the manufacture of pigments, grinding processes and dryers are the main causes of fires. Prussian blue and chrome yellow are especially hazardous.

Shipping containers should be strong with tight closures, and if they are not, the purchaser should transfer the contents to water-tight containers for storage.

Dry colors represent considerable value and are subject to heavy water damage. Some may ignite spontaneously if they become wet. Colors should be stored in separate stock rooms, if possible, and adequate protection from sprinklers by waterproof covers over poor containers should be provided.

FLASH POINT

Material	Closed Cup °F
Acetone	0
Amyl acetate	76
Benzol	12
Butyl acetate	72
Castor oil	445
Dibutyl phthalate	315
Ethyl acetate	24
Ethyl alcohol (ethanol)	55
Gasoline	– 50
Glycerine	320
Kerosene	160–165
Linseed oil	435
Methyl alcohol (methanol)	54
Methyl ethyl ketone	30
Mineral spirits	100–110
Naphtha, V.M.&P.	20– 45
Toluol	40
Tung oil	552
Turpentine	95
Xylol	63

Certain inorganic colors may need special attention with respect to location and separation from organic colors.

Lampblack and carbon black are subject to spontaneous combustion when wet. They should be stored in a dry place.

Explosion Hazards.

Steam Boilers. It can be said that fired pressure-vessel explosions can be prevented if they are installed and maintained according to power-boiler codes. The insurance companies usually follow the American Society of Mechanical Engineers Code.

The operating personnel should be licensed.

There should be regular inspections by competent inspectors, and all equipment should be properly maintained. Even low-pressure and small boilers (usually operating below 15 lb pressure) can explode with great violence and destructive force. They require the same regular inspection and maintenance as heavier installations.

Air Compressors. Vessels holding compressed air must have sufficient strength to stand safely the pressures needed. The oil that is required to lubricate the valves of the compressor involve some risk. Only oils manufactured for compressors are recommended. Some oils will vaporize and be carried into the compressor air receiver, unless drained off frequently. Should any overheating occur, the vapors are likely to catch fire and explode.

Gases in Cylinders. Many gases, including oxygen, hydrogen, acetylene, liquefied petroleum gases, chlorine, and nitrogen, are distributed in cylinders under pressures running as high as 1800 psi. Standards for the safe handling and care of these containers include the following:

Oxygen. either in gas or liquid form will combine violently with oil or grease. Valves should never be oiled or greased.

Acetylene. when dissolved in acetone, acetylene can be safely stored under limited pressure. It will decompose explosively if compressed alone.

Chlorine Gas. Chlorine gas is very corrosive, and extra precautions must be taken to handle it safely.

Cylinders of any material should never be allowed to fall or to be bumped around. They should be kept away from heat or the rays of the sun. They should be stored away from combustible materials.

Railroad Shipping Labels for Shipping Hazardous Materials

Red label. Inflammable liquids include any liquid or mixture that gives off ignitible vapors at or below 80°F (Tagliabue's open-cup tester).)

Yellow label. Inflammable solids include all substances other than classified as explosives to cause fires by friction, moisture or chemical changes, oxidizing material including items such as: chlorates, permanganates, nitrates that yield oxygen in quantities to stimulate the combustion of organic matter.

White label. Corrosive liquids, strong mineral acids, and other strongly corrosive liquids, that are liable to cause fires when mixed with chemicals or organic material.

Red or green label (gas). Includes all inflammable or non-inflammable gases under pressure exceeding 25 psi at 70°F.

Protection and Classification of Records. The principal hazard to business records is destruction by fire and water. For more complete details of protection, consult the pamphlet *Protection of Records* by the National Fire Protection Association.

Classification

1. Vital. Needs the best protection practically obtainable. Records classed as vital are franchise, charters, deeds, abstracts, minutes of directors' meetings, easements, options, stock transfers, bond records, important contracts, general books, supporting papers, accounts receivable, tax returns, records of research and special industrial formulas. Old line-product formulas known to many employees would be classed as more than important but less than vital.

2. Important. Formulas of old line products, many statistical and research studies, accounting records which could be reproduced from

original source if necessary though at considerable labor and expense. Class 2 covers those records not valuable enough for Class 1.

3. Useful. General correspondence that would only cause inconvenience if lost although production and business could carry on.

Housekeeping

Maintaining high standards for a clean and orderly plant is a basic rule of fire prevention. The daily removal of waste and combustible materials is recommended. When not immediately removed, such materials should be kept in fire-resistive enclosures.

All cleaning rags and filter cloths should be disposed of in metal cans filled with water and removed at least once a day.

No combustible material should be near heat sources, such as furnaces, steam pipes, or radiators. Containers should be in good order, with no leaks. Identification of contents should be marked on containers. All tanks should be covered if possible. Safety cans and tanks used for washing purposes should be equipped with lids having fusible links.

Lockers, cupboards, and closets should be kept neat and free of unnecessary accumulations.

Excessive quantities of inflammable materials should not be allowed to accumulate but should be kept to a minimum and should not be stored near exits.

Areas outside the plant should be kept clear of accumulations of waste. Weeds should be cut down or eliminated. Hose houses and indicator valves should be free from obstruction, and snow should be removed in winter.

Good housekeeping will also reduce the cause of most accidents in all plants. The common variety of accidents which result from faulty training and bad housekeeping are responsible for more injuries and lost time than those directly related to the paint, varnish, and lacquer industry.

SAFETY AND HEALTH

The manufacture of paints, varnishes, and lacquers is not considered a dangerous occupation, but health hazards do exist in any plant where liquid and dry materials are handled.

The physical nature of certain pigments is such that irritation of the respiratory system and silicosis may be encouraged; the chemical properties of a limited number of pigments may have a toxic effect on workmen who have continual contact with these substances. Hoods over the machines or respiratory masks should be provided for the operations in which these conditions exist.

Most solvents are toxic to some extent in vapor-air mixtures that are inhaled; the obvious precaution is to provide sufficient ventilation to maintain a safe limit on vapor concentrations.

The solvents and diluents commonly associated with lacquers are more toxic than the ordinary petroleum thinners used in paint and varnish products.

The following table indicating the concentration of various liquids which are considered safe for 8 hr of continuous exposure and succeeding information covering health, clothing, and sanitary facilities are reprinted from *Safety in Lacquer Plants* by permission of C. L. Jones of the Hercules Powder Company.

SAFE CONCENTRATION OF CHEMICALS
(Assumed: 8 hours of exposure per 24 hours)

Name	Chemical Formula	Parts of Vapor per Million Parts of Air
Benzene	C_6H_6	100
Toluene	$C_6H_5(CH_3)$	200
Xylene	$C_6H_4(CH_3)_2$	200
Methyl alcohol	CH_3OH	200
Butyl alcohol	$CH_3(CH_2)_2CH_2OH$	200
Amyl alcohol	$CH_3(CH_2)_3CH_2OH$	56
Acetone	CH_3COCH_3	200 to 2110
Methyl ethyl ketone	$CH_3CH_2CH_3$	Below 3000
Ethyl acetate	$CH_3COOC_2H_5$	139
Butyl acetate	$CH_3COO(CH_2)_3CH_3$	400
Amyl acetate	$CH_3COO(CH_2)_4CH_3$	400

Another aspect of the health problem of some importance is dermatitis. Some of the solvents, colors, oils, resins, and other materials may cause dermatitis. While dermatitis may not be as serious a threat as systematic poisoning, it can and sometimes does cause considerable trouble and expense. Not all persons are affected, and of those affected not all are affected in the same way. One person may be immune to the effects of a certain material which another cannot tolerate.

For some materials, less data are available concerning their effect on the human skin than on their relation to systematic poisoning. However, in view of the importance of the subject of dermatitis and the economic consequences of such disabilities, every lacquer manufacturer and user of lacquers should be alert to the possibilities of occupational dermatitis developing among his employees.

This means that the user should ascertain from the manufacturer the experience at the latter's plant during manufacture; also, the user should obtain data as to the experience at other consumer plants, making sure that information is furnished as to conditions of exposure at the manufacturer's plants and at the plants of consumers. He

should make use of state and federal hygiene groups and professional dermatologists.

If it develops that cases of dermatitis have occurred, then the material should be used and handled cautiously. If the experience obtained from the manufacturer indicates that there have been a number of serious cases, it will probably be advisable to have the persons who are going to work with the material patch-tested by a competent industrial physician before exposure to the material commences. The physician selected preferably should be one with industrial experience akin to that obtainable in the paint, varnish, lacquer, and solvent industries. This is important; while the general practitioner may be a competent, sincere person, his lack of knowledge of the industrial field may lead him into situations and possible commitments which can be awkward, embarrassing, and expensive to all concerned.

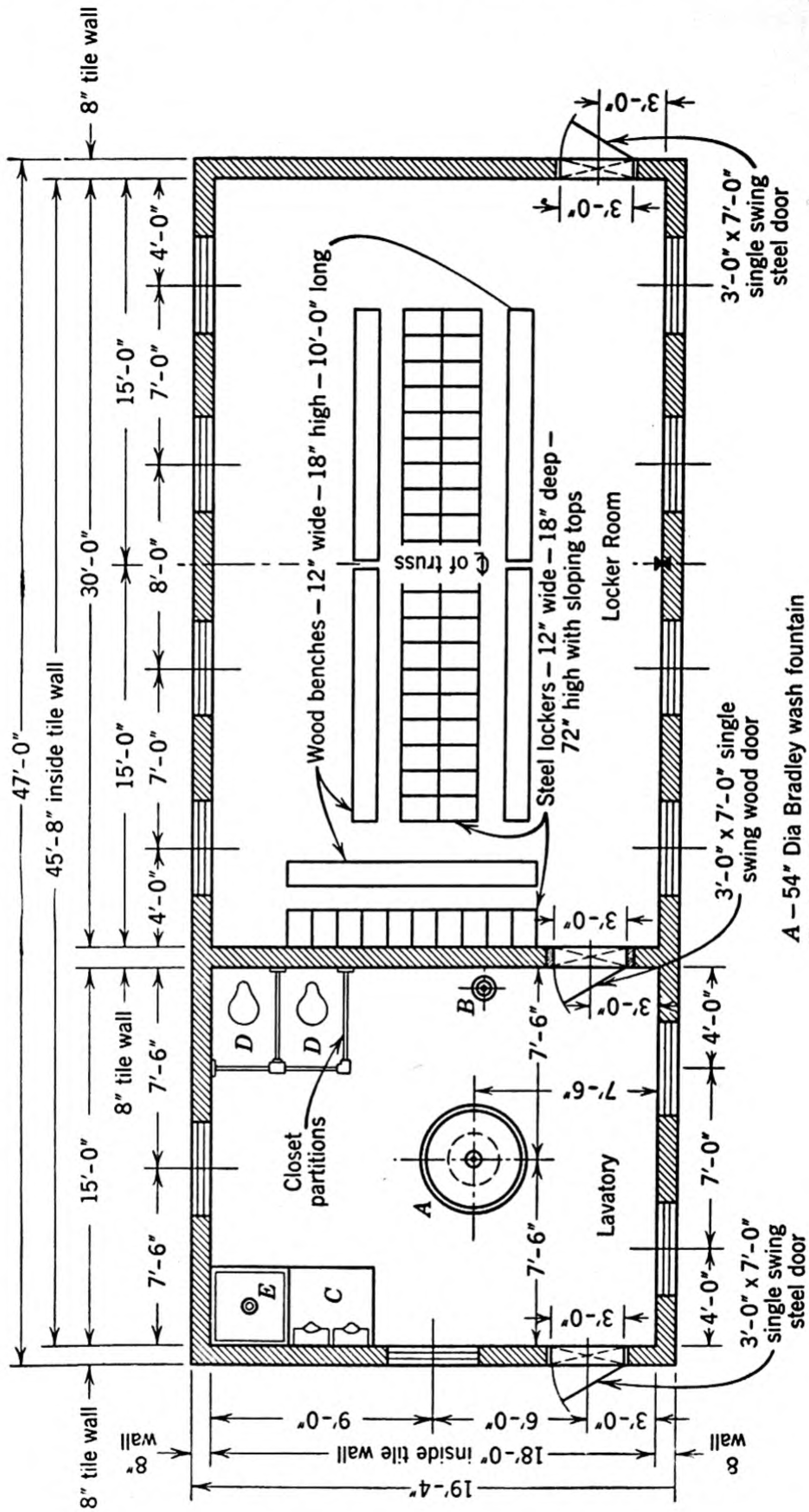
Assuming that reasonably complete "entrance" examinations were made prior to employment, subsequent examinations also should be made and preferably by the same industrial physician. The frequency should depend on the conditions at the plant and the nature of the materials handled. If toxic or irritant materials are handled, subsequent examinations should be carried out at fairly frequent intervals. By following this plan, conditions should be revealed before there is any permanent harm to the health of the affected person or persons, and remedial steps can be taken to correct the condition, in order to avoid having other persons affected, and to restore the affected persons to health.

Clothing

Protection against burns is of major importance. All those who work with flammable solvents should make it a practice to *keep fully clothed all the time—summer as well as winter—with shirt sleeves rolled down, shirt buttoned at the throat, and the head covered.* When so protected, it is probable that burns will be much less severe if a person is exposed to a flash fire. Persons only partly clothed when exposed to fires are likely to suffer serious, sometimes fatal, burns. Even better protection is afforded by the wearing of flameproofed clothing or uniforms. During recent years, a great many workers who have been exposed to severe fires while wearing flameproofed clothing have been protected from being burned severely. The flameproofing can be done by treating clothing with ammonium sulfamate or other equally satisfactory retardant salts.

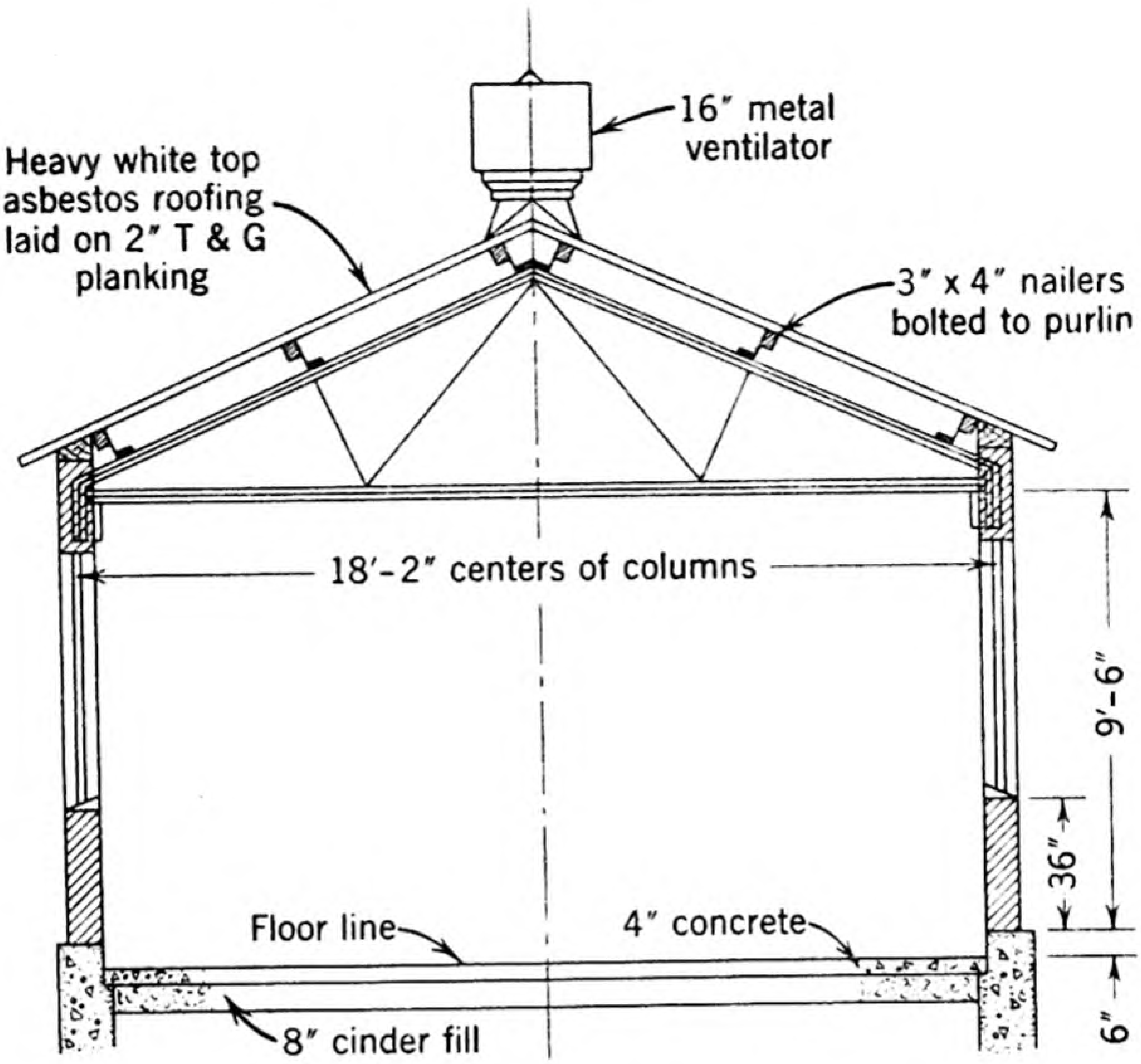
Sanitary Facilities

Under the heading of sanitary facilities are grouped discussions relative to such items as toilets, urinals, washing and bathing facilities, and eating and smoking places.



A – 54" Dia Bradley wash fountain
B – Drinking fountain
C – Urinals
D – Closet
E – Shower

Building plan for locker facilities.



Typical Section

It is advisable to set aside or erect a separate building equipped with proper sanitary facilities. The layout of a building intended to provide facilities for 60 persons is shown. If males and females are employed, it is necessary, of course, to provide separate rooms or buildings for each sex.

The following schedule has been used as a guide in providing sanitary facilities and will, in all but the most extraordinary cases, provide ample facilities.

Toilets: 100, or less, persons per shift—1 unit for each 20 persons; 100–500 persons per shift—1 unit for each 30 persons.
Urinals: 1 unit for each 50 men on a shift.
Showers: 1 unit for each 15 persons.
Wash basins: 1 unit for each 5 persons.

A 54-inch diameter unit such as a Bradley wash fountain is rated at 10 units; therefore this piece of equipment can serve 50 persons.

Hot-water tanks should be provided generally on the basis of 2 gal per capita; in other words, a building to care for 50 people should have a 100-gal hot-water tank. This quantity is a minimum; a larger storage tank is not a step in the wrong direction.

The sanitary and bathing facilities should be located in a room adjoining the locker room. A locker should be provided for each person

employed; some people advocate two lockers per person, one for work clothes and one for street clothes. Such provision certainly seems desirable. The lockers installed should be not smaller than 12 × 18 × 72 inches, equipped with sloping tops, well ventilated, and provided with a lock. A padlock is preferable to a built-in lock.

Adequate space should be provided in the locker room, particularly if this room is to be used also for an eating place. A better arrangement is to have, alongside the locker room, an eating and smoking room equipped with tables and benches. This latter arrangement is recommended because a locker room is not desirable as a lunchroom. By providing wash, locker, eating, and smoking places of proper and adequate design, several advantages are gained. These are: better morale, better housekeeping, decreased hazard, and improved product. All these advantages are more or less intangible, but important nevertheless. Where such facilities are provided, the employees invariably have a healthier and better attitude toward their jobs and their employer and there is greater pride in the job—which means a greater desire for neatness and order.

As to smoking, it is important to set aside a place where people may smoke with safety. If this isn't done, smokes may be "snitched," possibly at places where such smoking creates an added hazard. In addition, there may be resentment over the fact that the boss can smoke in his work place (office) and the employees cannot, or do not have a place where they may go for a smoke. By providing such a facility, one point over which resentment is likely to arise is removed.

Occupational Precautions

The importance of personal cleanliness in the control of dermatitis and other occupational disabilities cannot be overemphasized.

Protective clothing and other protective equipment, as well as creams and liquids to shield the worker from irritating substances, are needed. The cleaning of hands with thinners should be discouraged.

Adequate sanitary facilities, wash rooms, lockers, and shower room should be maintained in a clean and attractive manner. This will encourage employees to use them and prevent spread of infection.

Eating in work areas must be discouraged.

Persons exposed to toxic, caustic, or explosive materials should be supplied with double lockers and laundry facilities for their work clothing to encourage frequent changing of clothing.

According to the Safety Research Institute* intermittent or occasional

American Paint Journal, Vol. 33, No. 43, p. 56, July 18, 1949.

jobs involving the use of volatile solvents require as rigorous safety precautions as continuous operations, if substantial quantities of solvent or periods of time are involved.

Typical intermittent operations which require suitable precautions include tank cleaning and cleaning of machinery. The nature of the solvent employed will determine whether safeguards against both fire and health hazards are needed.

If it is impractical to provide mechanical ventilation for intermittent operations, workers should be protected from inhalation of the vapors by respirators approved for the type of solvent and the circumstances involved. Skin contact may be prevented by solvent-resistant gloves, protective creams, and aprons. The solvent should be kept in closed containers labeled with the necessary precautionary information, and workers should be informed of the dangers of improper procedures.

ACKNOWLEDGMENT

The major portion of this chapter has been prepared by R. E. Blackwell of the Lowe Brothers Company, and other sections have been reprinted with permission from *Safety in Lacquer Plants* by C. L. Jones of the Hercules Powder Company. Their contributions on the important subject of fire protection and industrial health are gratefully acknowledged by the editors.

OFFICIAL DIGEST BIBLIOGRAPHY

Ayers, H. R., "Good Housekeeping," p. 8 (June, 1928).

Becker, H. T., "Good Housekeeping," p. 7, (Sept., 1928).

Belyea, A. C., "Safety and Hazards in Handling Solvents in Paint and Varnish Plants," p. 130 (Feb., 1950).

Bernhardt, D., Jr., "Fighting Paint Fires," p. 335 (June, 1947).

Cook, W. A., and L. E. Gordon, "Toxicity of Solvents," p. 124 (Feb., 1950).

Farrell, L. G., "Static and Flowing Liquids," p. 465 (Oct., 1942).

Freck, S. G., "The Use of Carbon Dioxide Fire Protection," p. 277 (Dec., 1930).

Hoagland, I. G., "Automatic Control of Fire in the Paint and Varnish Industry," p. 7 (July, 1925).

Howe, K. J., "Consolidated Report on Standardizing Paints for Industrial Piping," p. 9 (Jan., 1942).

Jones, C. L., "Safety in Lacquer Manufacture," p. 145 (Feb., 1950).

Kleissler, A. J., "Ventilation, Fume and Dust Control in the Paint Industry," p. 133 (Feb., 1950).

Loney, D. R., "Fire Prevention and Control," p. 367 (Dec., 1934).

Miner, H. L., "Safety Color Code Helps in Preventing Personal Injuries," p. 141 (Feb., 1950).

Pitt, W. J., "Injury from Exposure to Materials which May Contain Benzol," p. 523 (May, 1931).

Pomeroy, W. E., "Good Housekeeping," p. 245 (June, 1936).

Riddell, A. R., "Benzol Poisoning," p. 442 (Mar., 1941).

Segrave, H. J., "Respiratory Protection in the Paint and Varnish Industry," p. 130 (Feb., 1950).

Shaw, J. S., "Safety and Health Hazards," p. 17 (Jan., 1941).
Sulzberger, F. L., "Good Housekeeping," p. 1 (Mar., 1928).
Teter, H. P., "Snuffing Out Fire with CO_2 Extinguishers," p. 241 (Nov., 1930).
Whiteway, P. J., "Fire Prevention," p. 4 (Feb., 1921).

ADDITIONAL FEDERATION OF PAINT AND VARNISH PRODUCTION CLUB PAPERS

Binswanger, J., "Spontaneous Combustion of Colors, Dry and Mixed with Oils," *NPVLA Sci. Sec. Cir.*, p. 292 (June, 1923).
Kansas City Club, "Health Hazards in the Paint, Varnish and Lacquer Industry," *Federation of Paint and Varnish Production Clubs, Tech. Proc.*, p. 67 (1941).
Toronto Club, "Fire Protection in a Paint and Varnish Factory," *NPVLA Sci. Sec. Cir.*, p. 397 (Nov., 1936).

INDEX

JAMMU & KASHMIR UNIVERSITY LIBRARY No 10672 Dt 23.4.72.
ALLAMA IQBAL LIBRARY
10672